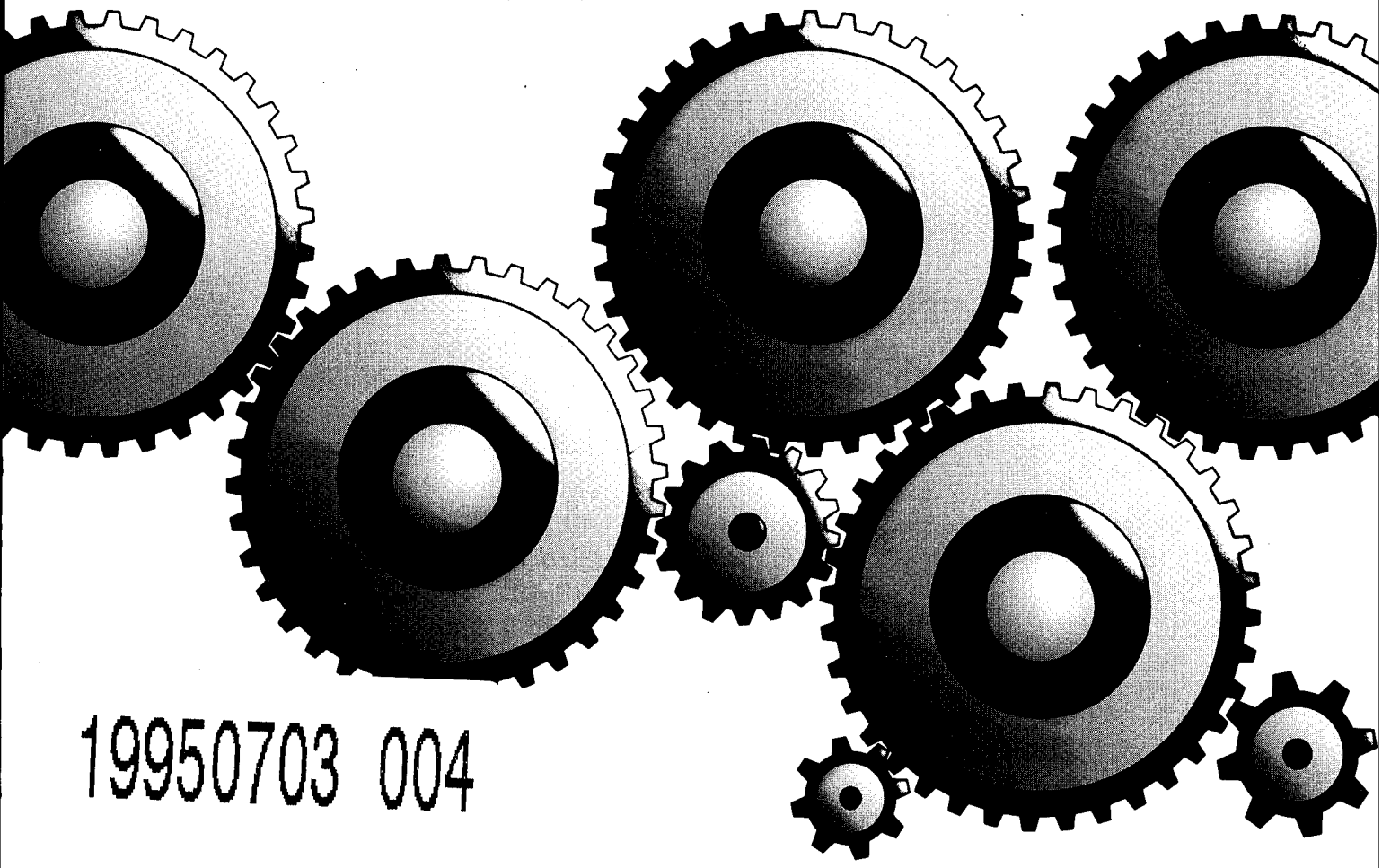
U.S. Army Corps of Engineers
Water Resources Support Center
Institute for Water Resources

Infrastructure in the 21st Century Economy :

An Interim Report - Volume I
The Dimensions of Public Works' Effects on Growth and Industry



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13. ABSTRACT *(Maximum 200 words)*

This interim report is a follow-up to a July 1993 publication entitled "Infrastructure in the 21st Century Economy: A Review of the Issues and Outline of a Study of the Impacts of Federal Infrastructure Investments" (IWR Report 93-FIS-4). That first report described the beginning of the effort in which the Corps presented a "strawman" scope of work to three different panels composed of professional economists and other staff from Federal Agencies, Congress and academia, and solicited participation in devising a concrete research plan.

This report describes developments since that initial workplan was articulated and is printed in three volumes. This volume (Volume 1) contains an overview of the research effort as it is now being implemented, namely three related research tracks to capture the different dimensions of infrastructure's effects on the economy. These tracts are: a Computable General Equilibrium (CGE) approach; an econometric cost function/productivity approach; and an endogenous dynamic growth approach.

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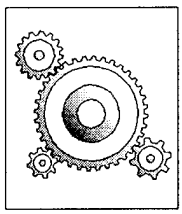


The Federal Infrastructure Strategy Program

INFRASTRUCTURE IN THE 21ST CENTURY ECONOMY:

AN INTERIM REPORT - VOLUME 1 THE DIMENSIONS OF PUBLIC WORKS' EFFECTS ON GROWTH AND INDUSTRY

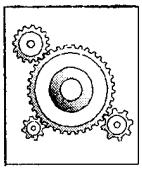
By:

Cameron Gordon

Institute for Water Resources
U.S. Army Corps of Engineers

February 1994

IWR REPORT 94-FIS-7



AN INTERIM REPORT - VOLUME 1
THE DIMENSIONS OF PUBLIC WORKS' EFFECTS ON GROWTH AND INDUSTRY

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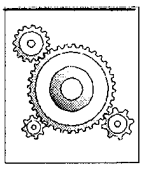


ACKNOWLEDGEMENTS

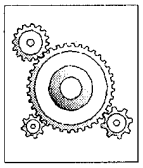
This report presents the interim developments in a study of the economic impacts of Federal infrastructure investments in transportation, water resources and supply, and waste management and is one element of a broad administrative directive, undertaken by the U.S. Army Corps of Engineers, and known as the Federal Infrastructure Strategy (FIS).

Special thanks are given to members of the interagency advisory panel which reviewed and analyzed many products and guided the study since its inception. Members in that panel which participated in the interim review meeting came from the Bureau of Reclamation of the U.S. Department of the Interior, the Federal Aviation Administration, Federal Highway Administration and Federal Rail Administration of the Department of Transportation, the Economic Research Service of the U.S. Department of Agriculture, the U.S. Department of the Army, the U.S. Office of Management and Budget, Jack Faucett Associates, the Upjohn Institute of Employment Studies, and the National Science Foundation. Representatives of the U.S. Environmental Protection Agency also provided guidance and useful input. The study's current progress would not have been possible without the vision and contributions of Dr. Charles Hulten of the University of Maryland at College Park, Dr. David Aschauer of Bates College, and Dr. M. Ishaq Nadiri of New York University, and the efforts of staff at Apogee Research, Inc.

Policy guidance for the FIS program is provided by the Office of the Assistant Secretary of the Army (Civil Works) through Dr. Robert N. Stearns, Deputy Assistant Secretary for Project Management, while program execution is overseen by the Corps of Engineers Directorate of Civil Works through Donald Kisicki, Chief, Office of Interagency and International Activities.

The Corps Institute for Water Resources (IWR) has detailed management responsibility for the FIS program under the direction of Dr. Eugene Z. Stakhiv, Chief, Policy and Special Studies Division, and the FIS Study Team which includes Mr. Robert A. Pietrowsky, Program Manager, Mr. Cameron Gordon, Economic Studies Manager, and Mr. James F. Thompson, Jr., Engineering Studies Manager. Mr. Kyle Schilling is Director of the Institute.

This report is presented in three volumes and was prepared under the supervision of Mr. Cameron Gordon, who also wrote the introduction to Volume 1 and prepared the paraphrase proceedings in that volume. Ms. Arlene Nurthen of IWR deserves recognition for her efforts in editing and formatting this report for publication.



AN INTERIM REPORT - VOLUME 1
THE DIMENSIONS OF PUBLIC WORKS' EFFECTS ON GROWTH AND INDUSTRY

PURPOSE OF THIS REPORT

The Federal Infrastructure Strategy (FIS) Program is a collaborative interagency study facilitated by the U.S. Army Corps of Engineers Institute for Water Resources designed to develop and stimulate implementation of an effective policy for managing and maintaining the nation's public works. This report presents developments in one element of that study, namely an effort to delineate and understand the effects of Federal infrastructure investments on the structure and functioning of the U.S. economy and the overall quality of life.

This interim report is a follow-up to a July 1993 publication entitled Infrastructure in the 21st Century Economy: A Review of the Issues and Outline of a Study of the Impacts of Federal Infrastructure Investments (IWR Report 93-FIS-4). That first report described the beginning of the effort in which the Corps presented a "strawman" scope of work to three different panels composed of professional economists and other staff from Federal agencies, Congress and academia, and solicited participation in devising a concrete research plan.

This report describes developments since that initial workplan was articulated and is printed in three volumes. This volume (**Volume 1**) contains an overview of the research effort as it is now being implemented, namely three related research tracks to capture the different dimensions of infrastructure's effects on the economy. The introduction to this volume lays out the separate research tracks - one for "telling the story" of how infrastructure investment affects economic structure, one for estimating those impacts numerically, and one for measuring the long-run impact on the macreoconomy - and describes the process which resulted in this research design. Following the introduction is a paraphrase proceedings of the panel meeting, held in October of 1993, in which the research design was analyzed and discussed.

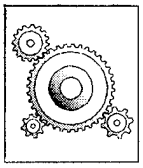
Volume 2 contains the three technical papers which developed and documented the research approaches which form this study.

* The first paper, by Dr. Charles Hulten of the University of Maryland at College Park, describes the different theoretical ways in which public capital moves through the economy and suggests that a model known as a Computable General Equilibrium (CGE) model be used to capture and delineate these effects.

* The second paper, by Dr. David Aschauer of Bates College, analyzes how public capital affects the overall economy in the long-run. He describes what is called a dynamic endogenous growth model which will be used to capture these long-term effects and estimate the "optimal" long-run level of public investment as well as how this optimum can be affected by different methods of financing (e.g. deficit versus taxes).

* The third paper, by Dr. Ishaq Nadiri of New York University, addresses the effect of public capital on specific industries and describes an econometric framework, using what are known as cost functions, for estimating infrastructure's impact on productivity within and across different sectors of the economy.

Volume 3 contains the details of a database on public capital collected and developed by Apogee Research, Inc. These data, and other information currently being collected, will feed into all three research tracks, providing for consistency in each of those efforts in the data being analyzed (though one approach may need additional data that another does not). The datasets which have been collected are on investment flows (i.e. annual investments) and capital stocks (collections of annual investments, netting out depreciation) for Federal expenditures in the areas of transportation, water resources and supply, and waste management.



AN INTERIM REPORT - VOLUME 1
THE DIMENSIONS OF PUBLIC WORKS' EFFECTS ON GROWTH AND INDUSTRY

INTRODUCTION

The Issue

In fiscal year 1993, the Federal government made direct investments of $19.1 billion in physical capital for nondefense purposes and indirectly invested another $31.2 billion through grants to State and local governments.[1] These annual investments are substantial and yet policymakers often have little idea of the impacts of this spending on the economy, on local areas, and on quality of life.

Determination of the proper level and allocation of infrastructure investment is a difficult and multifaceted problem. Public works spending has many different kinds of impacts, both at the "micro" level of an individual project and locality and at the "macro" level of a collection of projects in many dispersed localities considered on a national scale. A particular investment may look efficient when considered individually, but may not appear so when considered as part of a larger investment plan. The converse also holds.

In addition, infrastructure has many costs and benefits which are not captured by the private market and which may be far more important than the economic impacts which are reflected in market prices and transactions. A transportation investment which allows certain segments of the population such as the elderly to travel more readily may do little to increase national income, but may accomplish a great deal to improve the quality of life of the people affected. Similarly, making a harbor's waters fishable and swimmable may have little impact on the commerce in that harbor, but may have a great impact on the community's enjoyment of that harbor. Just because many infrastructure effects are not captured by market accounts does not make them any less important.

Background: The Initial Effort

It was in this context that the U.S. Army Corps of Engineers, Institute for Water Resources began conducting a study of the economic impacts of Federal infrastructure investments. The purpose of the study is "to assess the total rate of return on planned Federally provided and leveraged capital spending and capital stock in selected categories of infrastructure; understand the effects that these investments may have on economic activity; and examine and compare a number of methodologies for assessing this impact."[2]

The intent of the study was to act as a catalyst and facilitator, bringing together representation from different Federal agencies and academic institutions to exchange ideas and develop a scope of work which would be both policy-relevant and intellectually sound. To this end, the Corps convened a series of three workshops, attended by personnel from a wide range of Federal agencies, Congressional organizations and colleges and universities, to develop a study plan and to determine appropriate means of carrying out that plan. The details of those workshops, and the initial plan which was formulated are contained in the report, Infrastructure in the 21st Century Economy, by Cameron Gordon, issued July 1993 as IWR Report 93-FIS-4.

It was recognized at the time that fulfillment of this purpose would be no easy task; resources and time were limited and the questions to be answered were inherently difficult. To ensure that the work done would be worthwhile, study participants suggested three guiding principles:

* **Be Original**: Collect new data, or bring previously unused or internally used information, into the public domain;

* **Be Comprehensive**: Consider infrastructure as a network;

* **Be Policy-Oriented**: focus on how Federal expenditures affect, and are affected by, the structure of the economy.[3]

After much discussion, four broad sets of tasks were outlined to accomplish these purposes. These were to:

1. Develop an **overall framework** to account for the broad costs and benefits of Federal infrastructure investment and integrate them into a single conceptual view of the world.

2. Collect more **comprehensive data** on the stocks of public capital, the flow of services that are derived from those stocks, and the investment and depreciation streams which increase or decrease these capital stocks, providing as many different levels of aggregation as possible.

3. Compare, in a controlled fashion, **different methods** for analyzing infrastructure impacts, in order to differentiate real economic impacts of infrastructure from the effects of alternative methodological assumptions.

4. **Simulate future impacts,** since policymakers are concerned with the prospective effects of their policies.[4]

The development of an overall accounting framework was felt to be useful to organize information and clarify the relationship of investments to disparate sorts of impacts, particularly highlighting the relationship between market effects, the primary focus of the study, and nonmarket effects; collection of more complete data ranging from aggregate macro-level data all the way down to micro-level detail would fill out the accounting framework to the fullest possible extent; analysis of the data with different methods might clarify the way in which different methodologies affect estimates of impacts; and future simulations would result in estimates useful to decisionmakers.

After the initial workshops were concluded with a final meeting on November 6, 1992, work on the various parts of the effort began. This constituted Phase 1 of the effort in which Apogee Research, Inc. of Bethesda, Maryland was retained to collect new data, while M. Ishaq Nadiri of New York University, Charles Hulten of the University of Maryland at College Park, and David Aschauer of Bates College began working on developing conceptual approaches which could be implemented. Work proceeded over the coming months so that by October of 1993, the data collection was largely complete, and Drs. Nadiri, Hulten and Aschauer had developed proposals for modelling approaches to utilize, analyze and understand this data.

An Evolution

These efforts were reviewed at a progress meeting, held on October 6, 1993. The results of the meeting showed that much had been accomplished and that these accomplishments had caused the effort to evolve in promising but somewhat unexpected ways. As one participant put it: "You know the pendulum on these meetings has swung up and back but hopefully each time we have some more information and I think we do."[5]

Specifically, Apogee had collected a detailed data set for Federal investments in water resources, waste management and transportation, bringing into this domain some previously under-utilized data from Federal agencies, particularly the Corps of Engineers and Federal Highway Administration. Apogee had also estimated stocks of public capital using a number of alternative assumptions about depreciation rates, and had analyzed the effects that those varying assumptions had on final measures of capital stock.

On the conceptual side, Charles Hulten discussed how the micro-economy functions according to standard economic theory and showed how that economy can be altered once public capital is introduced. He proposed a way in which this theoretical understanding of the economy could be modelled and used to analyze and better understand the way in which infrastructure affects, and is affected by, economic structure. David Aschauer focused on the macro-economic picture, proposing to estimate a model which would measure the impact of the total public capital stock on long-run economic growth and further examining the impact that different financing methods, e.g. deficit finance versus taxes, might have on that growth. Finally, M. Ishaq Nadiri proposed to use the data which had been collected to estimate the different components of productivity growth, including that which might be attributable to public capital, and to measure the differential impacts that infrastructure has on different industry cost structures.

Participants generally felt that the purpose of the study and the problems that needed to be addressed were still salient. The size and nature of the payoffs to Federal infrastructure investments continued to be murky, and the debate over appropriate policy actions remained divided. That division needed to be narrowed, and the sources of disagreement needed to be better understood, particularly since investment decisions continued to have to be made. Charles Hulten put the matter in perspective:

> One camp says that there should be a lot more investment, while others say that there is enough investment, and up to now neither camp has credibility. On the one hand, the macro approach exists in a sort of void unconnected back to any of the intuitions which people think they have now....By the same token, benefit-cost analysis is allegedly drawn too narrowly... One of the reasons that I thought this project would be worthwhile was

that we could build up our intuitions and understand when those high elasticities might be justified.[6]

The past eleven months had also indicated that the task of clarifying the issue and coming up with firm insights was even more subtle than originally thought. The general sense of participants was that the next phase of work needed to (1) analyze the different dimensions of the problem - i.e. the micro and macro dimensions and short- and long-run dimensions - and link these different dimensions as much as possible; (2) use different methods of analysis in a complementary way, where different aspects of the problem would be tackled with the method best suited to disentangling it; and (3) explicitly focus on telling the story of how infrastructure affects the economy and not just on measurement of how big those impacts might be.

(1) Analyzing the Dimensions of the Problem

Of the many possible dimensions of public capital's impact, three possible dimensions are summarized below in Figure 1. These dimensions are the time-frame of analysis; the complexity of analysis; and the level of analysis.

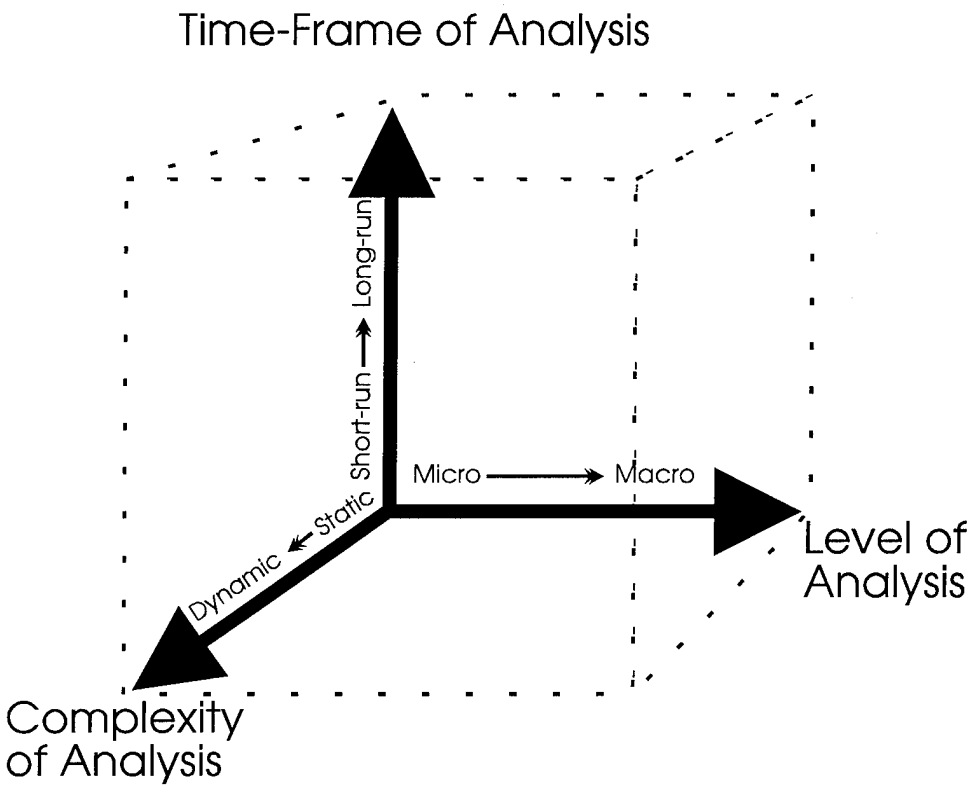


Figure 1: Dimensions of Economic Impacts of Infrastructure

Level of analysis refers to the degree of detail or disaggregation. Thus, a given infrastructure project has an effect on the area in which it is located and the immediately surrounding area. This might be referred to as the "**micro**" impact of the project. In addition, a given project has effects which occur during the time in which it is built. This could be referred to as the "**short-run**" impact.

It stands to reason, of course, that Federal infrastructure investment does not just consist of one project but a collection of projects which make up a system or network. Similarly, a bunch of successive "short-runs" is soon long enough in its time span that it is no longer a short-run at all. Eventually, the analyst has to explain and understand the time-frame of analysis, namely the "**long-run**" and "**macro**" impacts of infrastructure as well as its short-run and micro-effects to fully comprehend the efficacy of public works investment.

In addition, one can look at a project's impact today and compare it with the same project's impact five years hence; that would be a "**static**" approach in which the only concern is the comparison of a situation at point in time with a situation at a different point in time. But one might also be concerned with the steps which had to be covered in moving from one situation to another. In this case, one would want to increase the complexity of analysis, namely adopt a "**dynamic**" approach.

The picture is complicated by the fact that public capital itself is a commodity with characteristics which make straightforward economic analysis potentially difficult, namely that it is often what economists refer to as a "**public good**". For example, an inland navigation improvement may result in total benefits which exceed costs. However, the investment may appear unattractive to private investors because it may be difficult to exclude users who didn't pay for the project and hence be difficult for the private investor to recover costs. The "publicness" of the good in this case, and the potential economies of scale, both justify public provision of the good, and make economic analysis of policy options more complicated.

All of these differing analytic perspectives must ultimately be taken into account for a full understanding of the economic impacts of infrastructure and the differing perspectives must be linked in a coherent way.

(2) Using Complementary Methods

The discussion above highlights the fact that a problem this many-sided seems to demand many different methods of analyzing it. A comment by Ishaq Nadiri sums up the overall (though not exclusive) sense of participants on the issue of using different methods to tackle different problems:

> This analytical marriage of benefit-cost analysis and macro-economic analysis is not around the corner....To me, as limited as these production and cost function methods are, we need to understand where the effects are and add additional information wherever we can get it....Econometrics uses averages in its estimates - an average price or what have you - while policy questions deal in increments. They are different approaches and it is going to be very difficult even to bring the approaches into conformity with one another. They are just different. I mean, one is going by railroad, the other going by truck.[7]

In short, with a problem as multidimensional and complex as infrastructure, a multiplicity of methods must be used, with some approaches best used for some problems, and other approaches used for others.

(3) Telling and Understanding the Infrastructure Story

It is not enough to estimate the size of impacts at different levels of detail and time in the economy: the structure of that economy still needs to be articulated so that the linkages between that investment and a particular economic outcome (for example, a change in employment mix) can be seen, understood, and measured.

In addition, policy-relevant research needs to be concerned with the implementation and analysis of policy options in practice. For example, some of the ways in which the government finances infrastructure have impacts which may be negative and which may overwhelm the positive impact of the spending itself. Deficit financing of an efficient public works investment may, if the investment is large enough, "crowd out" private investments by using up the available sources of funds and hence driving up interest rates. Similarly, if spending is financed primarily with taxes on capital sources, private savings and investment may fall even as public investment rises.

Finally, while theoretical models aid in a understanding a problem conceptually, there must be a translation from this conceptual understanding to procedures which can be used to evaluate whether real-life projects are worthwhile are not.

Phase 2 of the Effort

The discussion above indicates the challenges that phase 2 of the study is addressing. The overall products of this second phase could be expressed as follows:

1. The underlying structure of the economy, and the way in which public capital works in that economy, will be better described, particularly with respect to "anomalies" such as publicness of goods and external economies.

2. Specific elements of that economic structure, particularly industry and sectoral links, will be more fully documented, and the specific impacts of public capital on costs, output and other factors will be empirically tested and estimated.

3. The long-run growth implications of public capital investment, and the effects of different public financing alternatives on long-run growth, will be assessed.

4. The analogy between the introduction of public capital into a specific production or utility function in a general equilibrium model and the undertaking of a specific investment in the real world will be explored.

To obtain these products ultimately, four different but related research tracks have been decided on:

First the articulation of the basic structure of the economy will be accomplished along the lines proposed by Dr. Charles Hulten, in which a Computable General Equilibrium (CGE) model will be used as a point of departure. A CGE model is a representation of a market-clearing, static economy in which the objectives, preferences and technologies of, and interrelationships between, producers and consumers are fully articulated to the extent that the magnitudes of these various characteristics can be measured

(hence the "computable" in the title). Much as the assumptions underlying a theoretical model can be relaxed to increase its complexity and realism, the CGE model will be modified to take into account complications such as external economies and network effects. Simulations will be done in which public capital is introduced into the system at varying levels of aggregation (down to firm-level potentially) and at various points (e.g. particular industries). These simulation results will be used to: (a) trace through the sequence of effects of public capital in the economy; (b) develop criteria which would alert an analyst to situations where nonlinearities and other anomalies might exist; and (c) provide estimates of net effects where the impact of aggregation of gross sub-effects is apparent and can be compared to estimates arrived at by other methods (e.g. macro estimates).

Second, econometrically estimated cost-functions, as proposed by Dr. Ishaq Nadiri, will be used to develop and test more detailed cost-elasticity estimates of public capital and also to focus more closely on industry and sectoral effects of public capital. Conceptually, the cost function shows combinations of inputs, at given input prices, which minimize the cost of producing a level of output. In estimating such functions for different industries, one can begin to measure how public capital changes costs in different sectors. In addition, this effort will also develop an econometric framework for identifying and estimating the components of infrastructure's productivity impacts in various regions and industries.

Third, a dynamic endogenous and neoclassical growth modelling approach, as proposed by Dr. David Aschauer, using, in part, applicable results of the Nadiri and Hulten work, will be employed to estimate the optimal long-run ratio of public capital to private capital for the economy as a whole, and assess the effects of different public financing methods (e.g. a tax on labor versus a tax on capital as discussed above) on the net long-run economic impact of public capital investment.

Finally, the fourth track will extend the CGE framework, proposed by Hulten, relying on additional experts in the field of benefit-cost practices at the Federal level, to explore some applications of benefit-cost theory on specific (hypothetical) investments and their conceptual and practical links to the analogous introduction of public capital into specific production and utility functions in a general equilibrium setting, and vice-versa.

Work has already begun on these various tracks. A full development of all these research elements will take some time, but a basic implementation of these approaches, serving as a foundation for further work, will be completed by the end of the calendar year 1994, with a report to follow within a month.

An Outline of the Rest of This Report

The rest of this report is in three volumes. The first volume - this one - contains this introduction and the paraphrase proceedings of the October 6th 1993 review committee meeting, which ushered in and helped develop the second phase of the effort. The second volume contains three papers presented by Drs. Nadiri, Hulten and Aschauer at the review meeting which form the basis of the research tracks of phase two of the effort. The third volume contains the data report by Apogee Research which was also presented at the October 6th meeting. Taken together, these three volumes provide both a record of how the project has progressed, and spells out the conceptual basis upon which the current work is proceeding.

Endnotes

1. Budget of the United States, FY 1995, Volume 4, page 109, Table 8-1.

2. Gordon, 1993, p. 31.

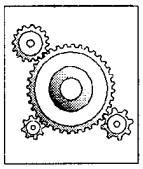
3. Gordon, 1993, p. 17.

4. Gordon, 1993, pp. 21-22.

5. see page 46 of proceedings in this volume.

6. See page 47 of the proceedings in this volume.

7. See page 48 of the proceedings in this volume.



AN INTERIM REPORT - VOLUME 1
THE DIMENSIONS OF PUBLIC WORKS' EFFECTS ON GROWTH AND INDUSTRY

Review meeting on "Assessing the Economic Effects of Planned Federal Infrastructure Investments," October 6, 1993.

PARAPHRASE PROCEEDINGS

ATTENDEES:

David Albright, Apogee Research, Inc.

David Aschauer, Bates College

Ken Chong, National Science Foundation

Brad Crowder, U.S. Department of the Interior, Bureau of Reclamation

Randall Eberts, Upjohn Institute of Employment Studies

Frank Emerson, U.S. Department of Transportation, Federal Aviation Administration

William Gelston, U.S. Department of Transportation, Federal Rail Administration

Cameron Gordon, U.S. Army Corps of Engineers, Institute for Water Resources

Chris Holleyman, Jack Faucett Associates, Inc.

Charles Hulten, University of Maryland, College Park

Arthur Jacoby, U.S. Department of Transportation, Federal Highways Administration

Randall Lyon, U.S. Office of Management and Budget

Brenda Moscoso, U.S. Department of Transportation, Federal Rail Administration

Richard Mudge, Apogee Research, Inc.

M. Ishaq Nadiri, New York University and National Bureau of Economic Research

Robert Pietrowsky, U.S. Army Corps of Engineers, Institute for Water Resources

Dennis Robinson, U.S. Army Corps of Engineers, Institute for Water Resources

Kenneth Rubin, Apogee Research, Inc.

Kyle Schilling, U.S. Army Corps of Engineers, Institute for Water Resources

Eugene Z. Stakhiv, U.S. Army Corps of Engineers, Institute for Water Resources

Norman Starler, U.S. Office of Management and Budget

Robert Stearns, U.S. Department of the Army

Pat Sullivan, U.S. Department of Agriculture, Economic Research Service

Martin Williams, National Science Foundation

AGENDA

Meeting for review and guidance on data collection and model development for the study "Assessing the Economic Effects of Planned Federal Infrastructure Investments."

U.S. Advisory Commission on Intergovernmental Relations (ACIR)
Suite 450, Conference Room
800 K Street, NW
Washington, D.C. 20009

Wednesday, October 6, 1993

9:00 am	**Welcome and Overview**
9:20 am	**Public Infrastructure Investment Data Report** David Albright, Project Manager Apogee Research, Inc.
10:20 am	**Break**
10:35 am	**Public Capital and Economic Growth: The Micro-Macro Linkages** Charles R. Hulten, Ph.D. University of Maryland
11:50-12:40 pm	**Lunch Break**
12:40 pm	**Public Capital, Productivity, and Macroeconomic Performance** David A. Aschauer, Ph.D. Bates College
2:00 pm	**Infrastructure Capital and Productivity Analysis: Cost- and Profit-Function Approaches** M. Ishaq Nadiri, Ph.D. New York University
3:20 pm	**Break**
3:30 pm	**Discussion of Next Steps**
4:30-5:00 pm	**Wrap-up and Adjourn**

Paraphrase Proceedings of October 6 Meeting

Welcome and Introduction

Schilling: Welcome to this meeting, sponsored and facilitated by the U.S. Army Corps of Engineers, Institute for Water Resources to review the progress made in this study of the economic impacts of planned Federal infrastructure investments.

It has been 10 months since we last met. Since then, the passage of the "Government Performance and Results Act of 1993" and release of the National Performance Review has brought to the fore the issue of government performance/productivity.

As you know, this study is part of an overall interagency program - the Federal Infrastructure Strategy (FIS) - which looks at performance in the various aspects of Federal public works, such as management, finance, Research & Development, and technology transfer.

Much has happened in this overall program as well. In particular, a national conference was held in July bringing together public works practitioners, analysts and managers in all levels of government. Basic principles and guidelines to obtain "high performance" infrastructure were outlined and ratified.[1]

Today's meeting is another step in one component of the FIS: an interagency project begun last year to assess infrastructure's relationship to economic growth and productivity. At that time, a basic scope of work was outlined and agreed upon.

You have before you the first products of that scope; these are modelling approaches by:

Dr. Charles Hulten, focusing on building a bridge between micro- and macro- analyses;

Dr. M. Ishaq Nadiri, focusing on cost-function analysis of infrastructure;

and Dr. David Aschauer, focusing on long-run dynamic growth models.

You also have before you a report on the infrastructure data collected by Apogee Research, Inc.

Now we are at a critical juncture. We will spend most of the day informing you about the progress of the effort and we have some time allotted at the end of the day to hear input from you on the direction of the program in addition to questions of clarification that may arise during the presentations.

But it is important to realize that we are not necessarily seeking to come to consensus here, nor is this the only time for feedback. There is a lot of information to cover and not much time to cover every detail. This is part of a process to make sure this effort will produce credible, intellectually sound and policy-relevant results. We want to respond to your questions and invite input at any time.

Thus we need to keep focused on getting some useful output at the end of the project, output which can be built upon. We need to address potential time and resource constraints, and we must stay concrete and constructive in our orientation.

We have here the project staff from Apogee and from the Institute for Water Resources (introduces staff). We are also pleased to have Bob Stearns with us who started this process with a list of eight questions that he and other policymakers had to face.[2] He hoped that this effort would provide some answers.

Stearns: I'm not going to answer those eight questions. My job is simply to introduce the proceedings. There have been lots of changes since we last met. The new administration has a genuine commitment to investing more in infrastructure. There is more emphasis on excellence in government. This administration really wants to increase investment in infrastructure, but there is a realization that the money is not there. All of these factors lead me to believe that this study and others will prove useful to policymakers. This effort is already having an effect on White House policy and will have more to the extent that we provide useful tools and information to help make decisions. Keep in mind that we are trying to produce tangible results which will help policymakers.

[There followed an introduction of people in the room and the panel consisting of Doctors Hulten, Aschauer, and Nadiri.]

Schilling: Bob, I don't think we're going to answer all of your eight questions when we get through, but hopefully we will make progress. David, I think I've said enough, and will hand it over to you.

Public Infrastructure Investment Data Report

Albright: Apogee Research is very pleased to be part of this effort and to be working with Professors Aschauer, Nadiri and Hulten. The purpose of the meeting is to be an open forum on the issues surrounding the project and the next steps to be taken in it. We would like to solicit comments and suggestions during the presentations and have also reserved some time at the end to discuss the future thrust of the work. We've asked the authors to address themselves to what the next steps are.

The primary purpose of the data report is to pull together a comprehensive data set which will be used to support the empirical analysis conducted using one or more of the approaches being developed now, and presented at this forum.

We were primarily focusing on collecting public expenditure data at all levels of government. There were two purposes here: to develop capital stocks and to develop data for use in a benefit-cost type of analysis which was forward-looking, i.e. which could be used for forecasting. Additionally, we collected private sector data largely from the Bureau of Economic Analysis (BEA) and other agencies.

Our general approach was to get as disaggregated data as possible. One level of disaggregation was geographic - State, county and city. We focused mainly on the State level since we believed that other complementary data were most readily available for States.

We also collected functional data in the 8 categories of highways, air transportation, mass transit, water supply, water resources wastewater treatment and solid waste management. We could not develop a good series of information for hazardous waste.

Finally, we also collected information on types of expenditures: maintenance, capital outlays, and other direct expenditures. The preference would have been to collect additional detail in capital spending,

such as construction and non-construction. We covered all levels of government: Federal, State and local.

We ended up settling on Government Finances Data which met most of the criteria set out above. It has all levels of government, has detail at the State level, and has the necessary information for functional categories. One of the disadvantages of Government Finances was the fact that Federal spending is not broken out by State but simply aggregated nationally. In addition, State and local government expenditures are, of course, identified by State, but for a limited time period of 1977 to 1990. It was not broken out by State for all the functional categories before that.

Another source of data was collected by the Congressional Budget Office (CBO). This series relies on State and local data from Government Finances, while the Federal data relies on the U.S. Office of Management and Budget (OMB) data, the primary difference being that OMB data are broken out by program or project, not function. Thus the CBO data and our data at the Federal level do not directly match.

We also collected Census data on Federal expenditures by States (which was preceded by a similar data set collected by Treasury.) That series contains Federal grants, by State, by program. We have that information for selected categories, running from 1969 to 1992. One of the problems is that only total grants are given, so we know that source of the money but not the use of the money. In addition, it was not directly comparable with other data-sets, particularly in functional categories. This information did allow us, however, to track trends in the distribution of grant monies by State, which makes future projections more sound.

We did try to collect data series from other agencies to expand on the Census and CBO series. Only two agencies offered improvements over Census and OMB: The Corps and the Federal Highway Administration (FHwA), both of which had more detail at the State level and some additional functional detail. The Corps data was used as the primary basis for the water resources capital stock estimates. We have not constructed a capital stocks series from the FHwA data because Michael Bell and Terese McGuire have constructed a capital stock from this information and we have not yet obtained this series.

We did collect some other information on grants from agencies, but this did not provide much information on direct capital spending.

One thing that we've attempted to do here is develop detailed functional capital stocks on a State-by-State basis. I have a hand-out which covers this process (see Figure 2)

Robinson: Was there any effort to break down the data into urban/rural or urban/nonurban?

Albright: Not at this point. There are some data available from Government Finances at the municipal level, and Census has some data at the county level, but we have not attempted to do much with this, mainly because other complementary data are available mainly at the State level. However, we may use some of this information for case studies.

We have created capital stocks for the functions listed. We have not yet created a capital stock for hazardous waste since the information for this category has not been adequate to do so.

INFRASTRUCTURE CATEGORIES

- Highways
- Air Transportation
- Mass Transit
- Water Supply
- Water Resources
  - Water Transport and Terminals
  - Corps of Engineers Navigation and Flood Control
- Waste Water Treatment (Sewerage)
- Solid Waste Management

ASSUMPTIONS

- Data sources and adjustments
  - National level
  - State level
- Allocation of capital outlays
  - Non-highways: structures and equipment
  - Highways: 52 percent paving; 26.5 percent grading; 21.5 percent structures
- Deflators
  - Non-highways: ENR Construction Index; PPI Capital Equipment
  - Highways: FHWA construction index (excavation, surfacing, structures)
- Asset lives
  - Non-highways:
    - 50 years structures
    - 15 years equipment
  - Highways:
    - 14 years paving
    - 80 years grading
    - 50 years structures
- Patterns of asset deterioration
  - Retirement
  - Decay
    - Efficiency, or economic, decay: $(T-\beta t)/(T-t)$
    - Straight-line decay
- State-specific capital stocks
  - Benchmark estimate
  - Deterioration rate

Figure 2 - Public Capital Stock

We have added some detail to Water Resources with Corps data. Water Transport and Terminals refers to Census data on State and local expenditures. Tennessee Valley Authority (TVA) data are not included because they do not have State-by-State breakdowns and because power generation is not broken out from other spending. Similarly, State data for Bureau of Reclamation expenditures is not readily available. Thus, the Water Transport and Terminals data consists of State and local expenditures drawn from Census, and is augmented with Corps of Engineers data. We feel we have covered the bulk of water resources expenditures with those two categories at all levels of government.

Gelston: Does water transport and terminals actually contain actual transportation expenses?

Albright: No, just spending on facilities by State and local governments, not spending on actual transportation of commodities.

Other than the Corps data, these categories include only State and local direct expenditures. They do not include direct Federal expenditures. Running down the list, highways do not include Federal direct spending on national parks, military bases and the like which are a small component of total spending. In air transportation, there is significant Federal expenditure but there really is only information on where the check was paid, not where the money was spent. Mass transit, water supply and wastewater treatment really do not have significant Federal direct components.

Starler: Is hydropower included?

Albright: Only in the Corps data. We have not included TVA or Bureau of Reclamation hydropower data because their categories are not so clearly disaggregated in all instances.

Stakhiv: Are you saying Federal grants are not direct expenditures?

Albright: No, Federal grants are indirect expenditures to State and local governments and they are included as part of State and local expenditures in Census. To avoid double-counting, we have not counted grants in Census.

Robinson: There is, I think, some detail on State and local expenditure at the State and local level. I may be wrong, but I thought that I remembered some instances where specific Federal sources of funds for capital and non-capital purposes was listed.

Albright: I don't know that that's true. My understanding is that the Census uses a revenue-expenditure accounting system and that in a few cases such as highways, Federal monies are listed separately on the revenues side but are not directly linked to the expenditures side. Of course one could assume that the Federal monies received are immediately spent.

Mudge: My sense is that on highways, that would be a reasonably good assumption but that in categories like mass transit, there are significant timing differences between when monies are received and when monies are spent.

Gelston: Did I understand that categories include municipal expenditures, e.g. such as local streets in the highways category?

Albright: Yes. The local government category goes down to the municipal level and sometimes below or beyond that to include things such as local airport authorities.

Williams: There are some established highway capital stocks. How does yours compare to those?

Albright: Our data are different from two recent efforts, one by Douglas Holtz-Eakin and the other by Michael Bell and Terese McGuire for the National Cooperative Highway Research Program (NCHRP). Holtz-Eakin estimates a total public capital stock and allocates that to the States. He benchmarks that total capital stock to the BEA totals, but he does not benchmark the functional categories in his series to the BEA functional categories, using the relative State shares instead. In that sense, his functional series is very different from our functional series.

We suspect our data is similar to that of Bell and McGuire's, but we haven't seen it yet.

In terms of other series, I would suspect that ours is different from that of others, because we are the first to use Census State data for all functional categories. The exception is highways data which has a longer history than even the Census data.

Jacoby: Would you reflect on the effect of the inclusion of routine maintenance on highway capital stocks and flows?

Albright: Right now, we use the perpetual inventory method, that accumulates investment flows over time, and in our method of doing it, accumulating capital outlays over time. Census lumps operations and maintenance (O&M) together, while FHwA does break maintenance out. We have not used that data directly. My understanding of what Bell and McGuire did is to use the perpetual inventory method for cumulating capital outlays and then augmenting that with the maintenance series, assuming a maintenance life of something like 4 years. Thus, the total capital stock is the sum of the capital outlays and the addition of maintenance to that stock.

Jacoby: Yes.

Albright: We haven't done anything like that here, but we are thinking about other possibilities for using the information. There is an implicit assumption, depending on what decay assumption you are using, regarding maintenance. Since we have direct information on maintenance for highways, we would like to use it, but there is the complication of estimating the effect of maintenance on highways of different age. I'd welcome any suggestions you might have.

Let me review our assumptions (see figure 1). In general, we tried to construct State capital stocks in a way to avoid imposing a bias on the results, i.e. to the extent gross output was the dependent variable, we tried to avoid picking independent variables which would inappropriately affect estimation of that independent variable.

At the State and national level, we used Government Finances data. First we had to develop a national level capital stock to allocate to the States and to benchmark to the individual State series. The Census State data starts at 1977, so we chose 1976 as a benchmark. The Census Government Finances national data starts in 1902, but only is reported every other year after 1932. We interpolated between 1932 and 1952 and assumed a constant relationship between capital and noncapital and construction and

nonconstruction spending (i.e. that they were in constant proportions). We did try some other methods such as using a regression, but that either caused negative numbers going back or it caused some funny proportions. This gave us our national capital stock numbers.

We took total capital outlays, and within Government Finances, we assumed that construction expenditures went for structures, while nonconstruction went for equipment. One problem with this assumption is that nonconstruction does include purchases of land. On average, though, this does not take us too far from Bell and McGuire's assumption of an 80-20 split. Their assumption is of a constant relationship, while our allows variation over time.

For the highways allocation of capital outlays we basically used Bell and McGuire's convention of breaking it down into paving, grading and structures, which is similar to what Eberts used.

Eberts: Which is basically similar to BEA numbers.

Albright: For construction prices we did have the Engineering-News Record price index which goes back to 1913. Otherwise, for equipment, we used the production price index (PPI) for capital equipment. That only goes back to 1947 and extended it by using the PPI for industrial commodities, benchmarked to the PPI in capital equipment in 1947.

For highways, we used the FHwA price indices which are three separate measures, one for excavation, one for surfacing and one for structures. That series changes its market basket in 1972 or 1975. We took the most recent series and appended that with the prior series, going back to 1921 and benchmarked to the current series to make sure it was consistent in levels.

For nonhighways, we used the BEA numbers for government structures and equipment - 50 years for structures and 15 years for equipment. Other alternatives exist, but BEA is the most widely used alternative. For highways we used Bell and McGuire's assumptions of 14 years for paving, 80 years for grading and 50 years for structures. These are constant proportions over time which we may modify if we identify consistent variations over time.

As for asset decay, I have used a paper by Jack Triplett at BEA who points out that depreciation is composed of retirement and decay. We have used something Triplett developed for retirement, which assumes that given the normal life, one should use a truncated normal distribution that begins at 45% of the asset life and ends at 155% of the asset life. For decay, we have used two different assumptions. The first assumption is that economic decay occurs (the efficiency formula on the sheet should be the inverse of what's there). T represents the total asset life, t represents the current time period, while beta represents the efficiency decay factor. We've used a beta of 0.9, consistent with Eberts, Faucett and others. This is somewhat arbitrary though. An alternative is the one-horse shay which assumes the asset produces and then drops off immediately in productivity. We may try that. We have tried the straight-line decay method used by BEA in constructing its capital stock estimates, to measure sensitivity of capital stock estimates to depreciation assumptions. The two factors which change are the level of the capital stock and the rate of decay. When comparing our highway series to the BEA series, the efficiency decay assumption yields the closest approximation. That may be due to the fact that BEA's benchmark year begins considerably before ours and this may allow our capital stock to catch up with the BEA numbers which decay must faster under straight-line decay.

Having gotten national numbers, we then used the 1976 national capital stock numbers and allocated it to States using total direct expenditure shares. That's consistent with what Holtz-Eakin did. The reason for doing that is that the total expenditure share (capital plus O&M spending) in each category is hopefully more reflective of the general level of capital stock in each State at the time, while capital outlays alone are going to be heavily affected by the projects being undertaken at any given time.

We then allocated the stocks to State by using the ratio of capital to noncapital spending, benchmarked to 1976. We excluded the 1980 to 1990 period from this calculation because there were many changes going on during that period and we wanted to avoid any bias because of that. I did try a few variations, such as using 1977 alone, 1977 to 1980, and 1977 to 1990.

Eberts: Did you try total expenditures to direct capital outlays as well (as opposed to capital spending /noncapital spending) for sensitivity analysis in constructing stocks?

Albright: No, but for some categories, where capital outlays make up the lion's share, such as highways, this may not make much difference. In other cases, that alternative ratio may not make much sense , such as solid waste where capital outlays make up only 50% of the total. One advantage of the procedure we've used is that they're done consistently across modes.

Having benchmarked the series to 1976, we had to develop the State-by-State series moving forward from 1977. To do that we have to construct an overall deterioration rate which combines the deterioration rate of structures and equipment over that period. The way we did it was consistent with Holtz-Eakin's approach, where we estimated the deterioration rate, assuming it to be constant across States and across time. We took the national level capital stock for each mode and determined what the deterioration rate would be from 1976 to 1990 and used that rate in the accumulation of investment flows from 1977 to 1990. What that means is that in 1990, the national capital stock will equal the sum of the State stocks, but will not be equal in the other years, though it should be reasonably close. Thus, in effect, the State data are benchmarked to 1990.

On a final note, since we had Corps data for States, we essentially followed the national level assumptions for each State capital stock in this case.

Stakhiv: I'm still not clear on how you aggregate and disaggregate the water resources categories.

Albright: If there is grant money, it is included in Census State and local data. The Corps data on direct expenditures is included but TVA and Bureau of Reclamation data were not included because it is not available consistently at the State level and does not break out power generation and water resources.

Hulten: For at least one of the categories, there does exist conditions data for at least one of the categories, namely the Performance Serviceability Ratings (PSR) data and condition assessments data for highways and bridges. One possibility is to try to incorporate this data into the analysis since it does speak directly to the measurement of the efficiency index and also provides State-by-State variation. Now, I've often heard it alleged that the PSR data is not greatly respected. Are these data reliable, or is it really just a political number as some people allege?

Jacoby: Recent PSR information, as part of the Highway Performance Management System (HPMS) is probably not too bad since it is a sample of about 1000 road segments and is supposed to be looked at every 3 months. Earlier PSR, or earlier PSI numbers are probably not too sure.

If you take the 14 year life for paving and see that 52 percent of highway spending is for paving, if that's a new highway and an upper level road system, that's probably a good estimate. But if that paving is for resurfacing and major improvement, then an asset life of 14 years is probably not too good a measure of that capital flow. I would wonder if there is some need to further disaggregate the paving category and estimate different service lives or utilize information in the needs report to get a hedonic measure of the value of the asset, or examine it for further discontinuities. For example, in 1977, I think, the Red Book changed and again in 1985. This is the specification for building a road and everybody follows that specification. Thus paving thickness requirements were changed in those two years and that would seem to be important.

Albright: I would agree in general. We do have capital outlays by State-administered highways and we have it for local and municipal roads, but my understanding is that the definitions of those change over time.

Jacoby: The State-administered highways are an artefact of the 1930's when the local and county governments went belly-up and ceded their legal rights to the roads to the States. So you've got Pennsylvania with a 114,000 mile system and 40,000 miles of State highway, and Oregon with 60,000 miles of road and 10,000 miles of State roads, and Virginia with literally 100% of roads under State jurisdiction. It's a Depression-era prehensile tail which keeps following you around which changes from State-to-State and has nothing to do with anything rational such as roads with the heaviest volume.

Mudge: One of the areas David and I have talked about is changing the average asset lives over time. For example, in the Interstate era, when it was all new construction, the life of paving was probably more than 14 years. Now, when you're doing more resurfacing, it's probably less. It's very hard to split this out from the construction data.

Jacoby: Some of the studies of life-cycle costing, where you're bringing your pavement back near but never up to the original condition may be useful, where the area under that horizontal line might be a measure of condition.

Robinson: My boss said to ask why the water resources capital stock is so low and why some of the dramatic drops occur? In the case of multipurpose capital stock, it wouldn't take you very long to get down to zero. (figure 2-11) Does this indicate we're going out of business?

Stearns: You're talking about substantial rehabilitation needs, so it shows that the system is getting pretty old.

Schilling: It is true that we are pretty much past the new project development area in the water resources area and are focused on rehabilitation.

Your question indicates to me that, given all the restrictive assumptions being employed, that we need to work together as agencies to get better information on assets. We need a common language on what the data means and how comparable they can be. What's the group feeling?

Hulten: I've worked with public capital stocks for years and they're very perplexing to measure. Public capital is not like private capital. An irreducible minimum for using the perpetual inventory method is knowing the efficiency of each individual investment which in turns relies upon the assumption that the productivity of each investment is independent of other public capital stock you have. In network types of capital, you are dealing with something very different where the productivity of a single investment depends completely on the capital stock already existing.

I believe that the state-of-the-art is advanced by what David has done and what he proposes to do. But I don't think you're going to find the answer, and look at it in terms of improving the underlying information base.

Mudge: Another problem is the assumption that the quality of investment has remained constant over 50 years. That's certainly questionable. One valuable contribution of this project is that we can do sensitivity analysis with different assumptions.

Schilling: We may not be able to compare programs now, but it is moving us closer to that goal and we can understand our own program better and identify the trends. I don't think we can draw inferences across the programs but can make inferences within the programs.

Stakhiv: I disagree. We're not in the business of collecting data for data's sake - we need to be able to answer questions we couldn't answer before. We have to construct a model which will yield new information.

Albright: One limitation of the data is that we are somewhat limited in the time periods covered for individual modes. Corps data goes back to 1936 and highways data goes back even longer. But the other series are more limited and we have to ask how we can extend the data backwards. My sense is that to get longer time series, we have to give up level of detail. For example, Government Finances combines solid waste management and wastewater treatment in one category for a longer time period.

Stakhiv: It may be worthwhile to look at TVA in a two or three State area where they provide all the services. There must be studies which show how TVA has affected regional economic development. To eliminate the TVA completely is troubling to me.

Albright: That would be true of the Bureau of Reclamation also.

Rubin: I might answer Kyle's assertion that by advancing the data and developing a common baseline, it makes detailed analysis that anyone might want to do more possible to do and more straightforward to interpret. The study plan which Cameron put before us more than a year ago had a lot of case study focus in it on the assumption that that would not only give us more richness in detail but more explanatory power. I think we're now in a much better position to do this type of analysis, whereas before we would have had a lot more baggage at this common level.

Stakhiv: True, but data collection is just a prerequisite for something else.

Gordon: And some of these issues will be focused on more directly in the modelling presentations which are coming up.

Jacoby: I have some concerns with what is not captured by capital stock, such as congestion.

Albright: There are performance data available for some of the modes.

Jacoby: Yes, but if you read a 1950 newspaper, you'll read people complaining about the congestion on Wisconsin Avenue. We've got a beltway now and there's still congestion. Now the volume-capacity ratio may be the same in both periods, but the output product is different. If you believe in declining marginal productivity of capital, it might be somewhat less nowadays, and that may be one of the explanations that we're in search of. These quality issues are often not captured in dollar values, although as a card-carrying economist I'm nailed to the wall for that.

Hulten: It's something that you whisper.

Public Capital and Economic Growth: The Micro-Macro Linkages

Hulten's Presentation: I saw that there are 3 principal elements of the scope of work (SOW). The first principal element is to develop and compare macro and micro estimates of the rate-of return. The second element is to develop simulations of the impacts of these investments. The third element is to compare the simulations derived from the different methods.

This is a very interesting and exciting project because there are two very different views of the public capital problem. One view is that public capital is a management problem plagued by bad political decisions. There has been a push to incorporate methods in decision-making which emphasize benefit-cost analysis. This push is implicit in the Intermodal Surface Transportation Efficiency Act's (ISTEA) planning mandates, and OMB circulars, and is very explicit in Representative Bob Carr's guidelines for submitting proposals to his transportation appropriations subcommittee. Benefit-cost (B\C) analysis, from everything I've heard, is a brake on bad projects.

The other view is the underinvestment problem, which Aschauer worked on and which Pat Choate started. His work seemed to indicate very high rates of return if you correlate various output measures with public capital investment.

This puts his work on a collision course with B\C analysis. If his work is true, one has to question whether B\C analysis is good at all to the extent there is underinvestment up to the level where public capital is up to 4 times more productive than private capital.

An alternative is to try to bring the two analyses together and to also examine whether the macro approach overstates the effects. That is my sense of the intent of this project.

This is what I tried to do in my paper, bringing in individual firms and examining issues of externality, increasing returns and publicness of the goods provided. I also looked at how the network effects played into the productivity of public capital.

My starting point is the perennial two-industry model which is a surrogate for a many-industry world. One industry uses public capital, and one does not. The question becomes: "What is the optimal diversion of resources to government from the private sector?"

I've chosen to model the world using the Production Possibility Frontier (PPF), with different PPF's associated with different levels of public capital stock. The envelope of these curves is the overall choice set. What happens then, is that a given capital stock is associated with a certain PPF and when preferences shift, we are constrained to that PPF even though optimization would require increased public investment to shift the PPF.

B\C analysis should be, in effect, analyzing the change in consumer surplus as we move from one state to another. That is the formal textbook analysis, although most B\C practitioners may not think of it as such. So the first step is to see how closely B\C practice accords with this model. David Aschauer wants to look at dynamic effects - I do not examine these - but one should get the story straight before complicating things.

I hasten to add that I am not a B\C practitioner. That raises the question of how one runs a fair lottery between B\C as actually practiced and macro analysis.

Next I shift to constant dollar Gross Domestic Product (GDP) measurement. This introduces the familiar Laspeyres price index problem of overstatement which is usually only a problem in industries such as the computer industry with compound price changes of 10% a year.

The basic problem remains and that is one of aggregation. If one is talking of 20 or 80 industries, there are already aggregations of heroic proportions. After all, what is the steel industry but a collection of individual firms? Moreover, one has to add up disparate types of investment into one category such as structures. Surely there is some slippage here. The question of how this slippage might affect estimates is an open question, using either method.

Aggregation could cause either method to overshoot or undershoot the measurement of equivalent variation. B\C analysis may count as benefits things which should not be counted by looking downstream, and, additionally, costs are typically underestimated. In the macroeconomic world, I've already alluded to the things which might be missed through aggregation. This says nothing about quality changes, which the Bureau of Labor Statistics (BLS) doesn't adjust for. After all, services seem to be stagnant, but if you've gone to the dentist lately, you'll note that there have been enormous changes over the past 30 years.

I stick to a static model, though I have developed a dynamic model for the World Bank. David uses the Solow and the endogenous growth model, while I split the difference with the Kass-Koopmans model. That model builds on the Arrow-Kurz world which has the fundamental result that the rate of return on social investments should be equal. That should be the fundamental result in a static or a dynamic model, though in a dynamic model there is allowance for feedbacks.

Finally, I have modelled public capital as a consumer good, but in many respects, the things which go on outside of the measured GNP accounts are often more important than the economic effects. For example, how does one account for the oft-made assertion that public investments were responsible for the decay of our inner cities?

I then focus on the economics. One of the big critiques of B\C analysis is that it misses the big picture. Now this doesn't necessarily need to be the case, since, if one goes back to equivalent variation, a good B\C analysis should capture all of the relevant effects. However, one has to be realistic in

assessing how B\C analysis is actually practiced, and here I would be willing to defer to almost any opinion since the practice of B\C analysis as opposed to the theory is not my area of expertise.

The externality and spillover problem has been examined theoretically in the macro case by Paul Romer in R&D (with a micro analogue developed by Mansfield), while Lucas has developed spillovers in human capital. This could be applied to highways, though it is not as clear here as in the R&D and education cases. For example, clearly highways are in the transportation production function, but what is it doing in the manufacturing production function? It is an intermediate input not a direct input into steel and is paid for in the market place. The problem is that when you do these correlations, you might find these patterns but you have to move backwards to determine how these come about.

I came away from this thinking that the real bang from infrastructure may not come from externality but from increasing returns. There have been a lot of papers written lately showing how one can get trapped at a suboptimal equilibrium. The big push is one example, where at low levels of investment, there is little incentive for private producers to expand, but if investment is increased, a lot more private investment is forthcoming. This is the classic "build-it-and-they-will-come" scenario. Krugman has expanded on this work to show that expectations alone may be enough to bring about a big push. Thus if people expect something to happen, then it will. Of course, not everyone holds to this notion. Nadiri has written with one of my colleagues, challenging this notion, suggesting that decreasing returns to scale are more often the case.

Next there is congestion. This is a difficult issue. Essentially, much infrastructure is a club good. At very low levels of use you have one result, but as networks fill up, you have a different result. Thus adding a lane to a completely uncongested road will not have much impact. This has serious implications for the macro production approach because there may be a disconnection between the public capital stock and the flow of services which generate the output which we're correlating the stock with.

Now, in the standard case, as you add more services from public capital you shift the PPF upward. With club goods, however, you can build facilities of different sizes and they don't move the PPF out proportionally. This occurs because the jointness of use causes the level of use to be correlated to level of services which the stock delivers. Thus the optimal level of capital stock will depend on how much that capital stock will be used in the future.

If one can adjust the quantity of capital to take into account the level of congestion, this not a serious problem - you just have some optimal level of congestion and you live with it. But there is a second complication and that is the increasing return problem. You just do not build a bridge half-way across the river and if you really think you will need an 8-lane bridge, you really should build it and not build a 4-lane bridge and expand it later. There is a very strong incentive to build in advance of need. This ends up affecting how we should weight depreciation and decay if we are going to try to capture efficiency loss in the depreciation factor.

An alternative strategy, which is going to be forced upon almost any research design, is to shove the congestion into the residual. But then you have the problem that if you shove too many things into the residual, then you have difficulty interpreting the residual. I don't have any bright ideas right now, but at least one has to incorporate measures such as vehicle miles travelled into the analysis.

Finally, I tackled the theory of networks. Infrastructure ties things together. This fact can make B\C analysis amazingly complex. This speaks directly to the issue of complementarity and substitutability. If a road is a substitute, you can't actually add up the roads, but must actually subtract from your capital stock the roads which are being used less because of the new investment. On the other hand new roads which are complements to existing roads lead to wholes which are greater than the sum of the parts.

This network effect also complicates the macro analysis. For example, if one calculates an output elasticity for all roads, it is difficult to interpret its meaning. In fact, you want elasticities for each different type of road and then use those elasticities, in effect, as the weights to aggregate things up. Where this aggregation bias leads is difficult to tell. My guess is that is this is one reason that sometimes infrastructure matters an awful lot. For example, I remember riding across the country in 1953 and it was excruciating. Every 5 miles there was town with a 25-mile an hour speed limit and a bunch of cops. But what do you do for an encore there? In this case, you've built your big links, and now will only do in-fill, many of which are decrements to public capital stock because of their substitutability. The same issue comes up with the information superhighway - are you going to get explosive growth, or is it simply in-fill around the existing AT&T/cable television network

This is where I stopped thinking. [Laughter] I think the useful path might be to keep the empirical track as it is and then also build a model from the ground up starting with firms, adding up to industries and do pure simulations where you can know what the parameters of each individual plant are in principle. In other words, do the simulation on a world in which you already know the structure of the world. Having built this model, one could then do a lottery by suggesting projects to be built in this world and tracing through the effects and then using B\C analysis in practice to see how many of these links were picked up.

Eberts: We're trying to replicate what is supposed to be the model, namely private-sector productivity analysis. But I could imagine putting a black box around a whole bunch of things from an assembly line to a branch plant to a whole industry sector and we would have black boxes within black box. Are we up against similar problems in private sector analysis as in public sector analysis?

Hulten: In many ways, yes. This calls up the old parable of the beekeeper and orchard grower. The solution is to merge the two and let them solve things through their own internal incentives. In public capital, we are concerned with the connectivity. If the road system were privately owned, we would not worry about the internal cost calculations being made, but with a public road system, we are concerned with making those calculations and identifying those links so we can make better decisions as if we were a private operation. However, I think the problem is less severe in the private sector case.

Lyon: I was wondering if you could restate what your thoughts are on increasing returns to scale. I think it's almost an instinctual OMB reaction. When you think infrastructure, you think high fixed costs and low marginal costs, but that can all be internalized in one's B\C analysis. But where is there any other analytical failure?

Hulten: The literature has tried to make a big deal in cross-country comparisons of these expectational traps. Of course, one has to say right up front that the U.S. is a developed economy and may be quite different from the other economies it is being compared to. Beyond that, the issue goes to the arguments that civic boosters make when building a stadium. If we don't build a stadium, we won't get a football

team. If we build it, they will come. This is a form of self-fulfilling prophecy. This has occupied macro-theory in recent years. There is an argument that can be made that, for underdeveloped economies, a lack of infrastructure has kept those regions from developing. Having said that, it is not clear that that is what is actually happening, nor is it the only possible explanation for underdevelopment.

Lyon: It seems that this is more likely a problem for private-sector analysis, where private sector analysts do not explicitly consider the preferences of other actors. But public analysts explicitly do consider all preferences. The problem, and granted, this is anecdotal, is that ridership estimates, for example, at least in mass transit, are usually way overstated. I can understand this self-fulfilling prophecy in the private sector, but it is less clear to me how this would occur in the public sector.

Hulten: Yes. Consider a situation where there are multiple equilibria. It is not clear to me how B\C analysis performs in this situation. My impression, from watching Congressional testimony over the last few years, is that if you want to make something happen, you can do it through the B\C ratio. But the real question is does this happen and if these multiple equilibria occur, how do the two different methods of calculating rates of return compare and capture them? This, it seems to me, is the sequence in which they should be investigated.

This is the area where a lot of people get their intuitions about infrastructure. It's easy to see in Nigeria, for example, that there is insufficient electricity-generating capacity, and that there would be a lot of benefit to improving that capacity. The World Bank has documented this sort of thing. It's also easy to see why improvements are not made. Does this sort of intuition apply to a developed nation like the United States? My gut reaction is to say that it does not, but there may be some cases where it does. In those cases where we think it might, the further question is whether B\C analysis will capture it and on that question, you'll have to tell me. I do not know.

Lyon: As an aside, there are plenty of white elephants in development projects.

Hulten: Exactly, and that is the project that I'm working on with the World Bank, trying to make them own up to some of their white elephants by doing an ex post comparison of their B\C analyses with the actual macroeconomic performance indicators.

This points up the asymmetry between private and public capital. Public capital is a background type variable - it's a club, and for it to be valuable, other types of things have to happen, and in many of these developing economies these things don't happen so you have this great road system with burros walking down the side.

Stearns: I have 3 questions. First, have we underinvested in public capital? Second, if so, is it because we've improperly applied the B\C tests to investment in the public sector. Third, if that's true, where is the biggest bang for the buck in changing B\C analysis so we can make better decisions?

Hulten: I don't believe we have underinvested, in answer to your first question, though I do believe public infrastructure is critical to economic growth. It all depends on the type of public capital. I do not think that you can make a good case that we have not put enough money into infrastructure.

Regarding your second question, I think we have managed our money very badly. An example is the highway construction grants which we've stayed with far too long. That program, and others, had

matching ratios that were far too low and the program lasted far too long, so it's no surprise that now we're getting a lot of potholes, as you would in any aging system. We also don't price road use. Finally, the overarching problem is that we don't apply B\C analysis is many instances. David Albright and Ken Rubin loaded me up with papers and I actually read some of them [laughter] and it's clear that in many instances B\C analysis is not done or ignored. There's a paper by Goodstein that shows that in two important regulatory decisions, EPA ignored B\C analysis.

This points up to me that we have to consider public investment as an investment, i.e. the use of savings for particular purposes. David Aschauer deserves a lot of credit for calling attention to the symmetry between public and private capital as a productive input. We can argue about where that symmetry breaks down, but we can all agree that we need to limit political investment criteria.

Gelston: Maybe it would be good to introduce risk assessment procedures that the private sector uses into public capital decisions; ridership projections are an example. On the other hand, there are public investments that may be made which the private sector would not make, but that the public may need. In other words, they're riskier investments. Is there no room for the public sector to make such investments. People are hot on high-speed rail, but there's no private money willing to come forward for it.

Hulten: My view is that it's very risky to trod where the private sector will not. There's a proposal by Moynihan to create an infrastructure fund which would tap private pension funds for infrastructure projects. A lot of people are very nervous about that. There are some good things that would be built as a result of that that would not be built otherwise, but there are also a lot of bad projects which would go forward as well.

Gelston: But then, in B\C analysis, we're not cranking in what the private sector would consider. Should we include this?

Hulten: I can't answer that.

Rubin: Traditional private sector analysis tries to account for the uncertainty of future events. I think that what's happened in the public sector is that political assertions have substituted for a proper assessment of uncertainty. That makes the B\C analysis skeptically received and lacking in credibility, even if the uncertainty analysis is done right. Can you change a political convention? I'm not certain about that.

Jacoby: You asked earlier that the road stopped at a certain point in the making of steel. I would suggest to you as a logistician that while there are a series of steps, there is a certain substitution function between inventories and transport and location and size of plant and market area and so forth. So I would suggest that the relationship of the input road into the making of steel isn't quite as vague as your comment suggested.

Second, in regard to the public good nature of the infrastructure, would the congestibility of the facility reduce the social indifference curve as well as the PPF? In addition, congestion at some point renders a public good a private good. That would imply that the social indifference curve would shift inwards, would it not?

Hulten: Indeed, that diagram is drawn prior to any of the complications we tried to hang on to it. As one incorporated these complications, this indifference curve would have to contain congestion in it, since that represents the limits to production and consumption. What would happen with congestion is that a false PPF is suggested to decisionmakers, and the question remains of whether and how those decisionmakers distinguish between the true frontier and the false frontier.

I do think that when you draw these frontiers, they do have to include all the cross-effects. That is why they're valuable, because they sweep all these possibilities into one black box and show you the most you can get. What happens with externality is that you get a false frontier and that is why you get suboptimal private decisions.

Jacoby: And that would be worsened with lumpiness in investment or the general observation that there are decreasing returns to highway infrastructure.

Hulten: Yes, and when this is important, it has to be modelled. That is why I suggested an approach where you start with the micro-units and build upward so you can see what they see and see what they're not seeing.

Let me answer your first question on roads. Krugman has done some work which shows that highways have some interesting spatial effects in manufacturing. In his model, there is an immobile agricultural sector with immobile factors which he calls peasants, and a mobile manufacturing sector. Thus you can't grow wheat just anywhere, but you can make steel anywhere. He shows that there are three parameters which are key to the problem. One is the increasing returns to scale in the manufacturing sector. The other is the transportation costs given the network that you actually have. The third is the magnitude of the demand of the people who don't shift around the network. He shows that if you have weak increasing returns, or none at all, or if you have very large immobile demand, or if you have very high transportation costs, you get a dispersion of manufacturing throughout that network to serve that immobile demand. Lowered transportation costs allow the manufacturing sector to exploit increasing returns, and the result is that you hear a giant sucking noise [laughter] as manufacturing moves to the low-cost areas in the network. Unfortunately, the model is too complicated to write down a solution. It has to be simulated. But the model does hold promise as an intuition building device.

Williams: You seem to be indicating that you take a micro-data approach to the problem. I think of some of the work that Diewert has done on regions with differing degrees of development. You would think that regions with high degrees of development would be affected differently from regions with low degrees of development and you have to incorporate the effect of development and congestion effects into these network effects.

Hulten: I agree.

Schilling: How do you think B\C analysis should take into account noneconomic effects such social effects?

Hulten: I don't have any practical knowledge here, but I do think it's a useful discipline to have people tell you what they think the benefits and costs will be, not in dollar terms but in usage terms, and hold them accountable.

Gordon: As I see it you've set up a typology starting with the simple case and working up towards more complicated situations. One question is how do you avoid setting up the model so that you find what you're looking for, i.e. if you expect that underdeveloped areas will benefit more from infrastructure than underdeveloped areas, how do avoid establishing a model that gives you what you expect? The second question goes to next steps. You lay out a lot of interesting questions, but to fully carry it out would go way beyond the resources and time we have available. We're practically oriented here, so the question I have is what's the triage - what should we give up if we have to?

Hulten: In answer to both questions, it's up to you [laughter and comic groans]. The real danger with any model is garbage in - garbage out and that you can assume your conclusions. I think that the Corps, if you pursue this route, and I hope you will, will have to determine which simulations are most useful for decisionmaking.

Stakhiv: You never answered Bob Stearns second question about where B\C analysis can be improved. I would suggest that the water resources model is a useful start. You didn't get five boxes of books on water resources B\C analysis for the average economist. That system is grounded in national economic development and the increments and decrements to it that different investments might bring. Now that system has to be improved somehow, and everybody has got ideas about how to improve it, but that's a useful starting point because I think that's the best accounting framework that exists in the Federal sector.

Hulten: I am so far away from practical application that I cannot support or reject that statement. Certainly, when I was in college, water resources was a very hot area, Otto Eckstein and so on, so I'm sure you're right and I just don't know about the practical element to know where you'd miss. You probably will miss, however

Stakhiv: Sure.

Public Capital, Productivity, and Macroeconomic Performance

Aschauer's presentation: The differences between my paper and Hulten's are numerous. I have a dynamic framework, he has a static framework; I use a macro-perspective, he uses a micro-perspective; I emphasize the simplicity of the world while he emphasizes its complexity.

There are also differences between my paper and Nadiri's. I am using the production function as a baseline, while Nadiri is estimating cost functions.

Note that in the short-run, we have to consider the relative efficiency of private versus public capital. We also have to worry about the means of financing - if the distortionary tax effect dominates the productivity effect, overall economic growth will be lowered. Finally, we have to be concerned about the type of growth we'll get from infrastructure. From a neoclassical framework we'll only get a temporary boost to output but no long-term effects.

The motivation for what I've sketched out is similar to what Hulten sketched out, namely the discrepancy between rates-of-return estimated by macro- versus micro-approaches and also between national and regional and smaller area estimates. Those are a couple of puzzles that I would like my own research to address.

Today I want to talk about two possible partial answers to those puzzles. One possible explanation is that the macro elasticity estimates do not fully account for the distortionary effects of taxation on long-run economic growth in an endogenous growth setting or the level of growth in a traditional neoclassical growth setting. The second partial answer I'll discuss is the possibility that the aggregate estimates are capturing spillover effects, perhaps externalities, from State and local areas, from the increased spending on public capital.

To motivate the first discussion I have a diagram (see Figure 3) where productivity growth is related to the ratio of public to private capital. And I've got a hypothetical set of points, call them States if you will, that will allow us to look at the relationship between productivity growth and public capital.

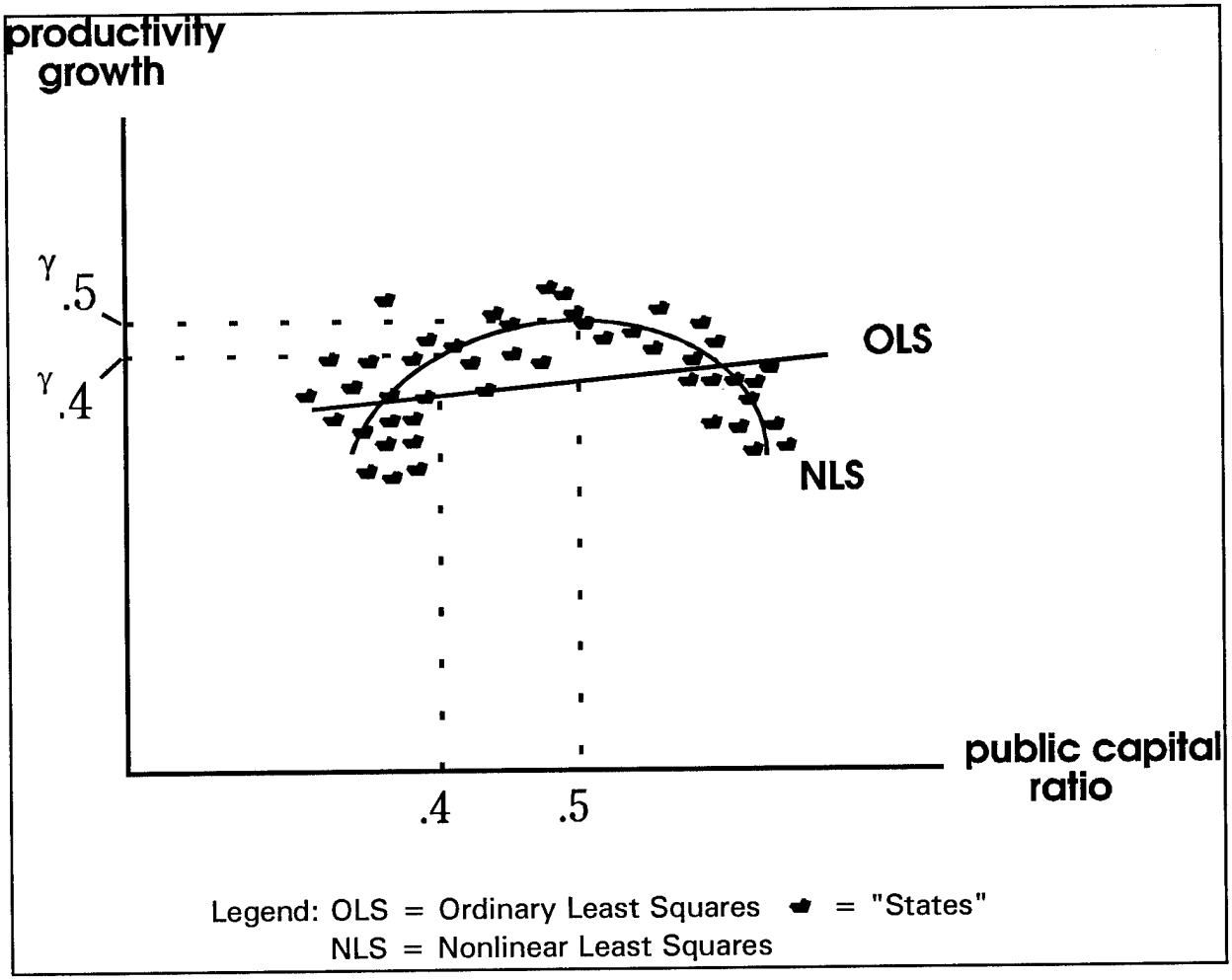


Figure 3 - Public Capital, Taxes, and Economic Growth

The idea would be that if we need to increase public capital through distortionary taxes, we'll get additions to productivity growth, but only up to a point. We'll get a positive effect only to the extent the productivity effect dominates the tax effect. At a certain point, here it is a ratio of public capital to private capital of 0.5 or 50%, productivity is maximized and after that point, the tax effect dominates and

productivity is adversely affected. This work builds on similar work that Robert Barro has done looking at cross-country data linking growth in output per person as opposed to productivity growth to government spending as a share of output and not the ratio of public capital to private capital. The algebra is somewhat similar but it is little more complicated because here we are worrying about the method of financing.

Suppose this theory is correct, that we have to finance public capital with a distortionary tax on output so that in the real world there is a nonlinear relationship between productivity growth and public capital. Thus we would expect to find a nonlinear relationship between those effects across States and in that case a linear regression would considerably mismeasure the productivity effect. So we must first check the empirical job we're doing.

Second this can rationalize the differences in the rate-of-return found in the macro framework versus the B\C framework. Putting the tax effect aside, if we find a large output elasticity from the production function, the estimated value would tend to be far greater, due to the mismeasurement mentioned above, than what we actually observe using B\C analysis.

Now consider spillover effects. Consider this table by Munnell (see Table 1). This is a highly selective table, as Hulten would point out. However, I think Charles Hulten and I would agree that there is some relationship between different regions, enough to warrant further research. It's a different matter as to whether you would want to run policy off of a particular estimate.

TABLE 1

PRODUCTION FUNCTION ESTIMATES

Researcher	Elasticity	Geographic Level
Aschauer (1989a)	0.39	National
Holtz-Eakin (1988)	0.39	National
Munnell (1990a)	0.34	National
Costa, Ellson, Martin (1987)	0.20	State
Eisner (1991)	0.17	State
Mera (1973)	0.20	Regions (Japan)
Munnell (1990b)	0.15	State
Duffy-Deno and Eberts (1989)	0.08	Metropolitan areas
Eberts (1986, 1990)	0.03	Metropolitan areas

Author's note: Results from first-difference model used by Aaron (1990), Hulten and Schwab (1991), and other critics are not included because they yielded implausible coefficients on the private inputs.
Source: Munnell (1993)

The research strategy I would like to draw out, given limited resources, is to focus on long-term effects rather than short-term, and focus on steady-state productivity levels in a neoclassical growth setting or steady-state long-term growth in an endogenous growth model. We would like to have information on whether public capital raises just the level of output, or whether it raises the rate of growth in an economy. Second, I would take as a valid that there is a reverse causation between public capital and growth, so I would like to endogenize public capital in some way to at least minimize the argument of reverse causation. As I said before, I would like to include the effects of distortionary taxes, the spillover effects and to make use of new public and private sector data being collected.

The basic model is where there is one production sector and two demand sectors of representative consumers and the government. There is a Cobb-Douglas production function where output per person is a function of labor per person and capital per person and the coefficients on private and public capital is alpha-K and alpha-G respectively.

I want look at two cases, at a minimum. One case is where the two alphas sum to less than one, which yields the neoclassical case where there are diminishing returns to capital. The other case is where these two alphas, or elasticities are equal to one, so that there are not declining returns to scale. Ideally private capital stock would be very broad but would also include human capital, but empirically that is quite difficult. In addition, I have only one type of public capital here, but that can easily be extended to take into account other types of government capital. Finally, one can work out all the effects here using different types of production function assumptions than I have used here.

Thus there is production going on in the economy. Income is being generated which is received by the representative consumer. The representative consumer would have to decide how to much to consume and how much to save which in this model is the same as how much to invest. This is an optimizing model of long-range growth. Savings rates are not just a given. Private investment is determined on the margin by the difference between the net marginal product (MP) of capital (K), and some measure of the impatience to consume, the marginal rate of time preference (MRTP). Some of the resources are going to the government in the form of tax revenues and for pedagogical reasons I'm having all government resources go into consumption, though one could have some go to investment.

I'm endogenizing by saying that in a steady-state situation, public investment will have to be at the same rate as private investment so that public to private capital will have to be constant in the steady state. Individual State governments are choosing this optimal ratio and how much they invest will depend on the amount of private capital available.

In a steady-state equilibrium, it is going to be the case that all variables are constant or they're going to be growing at the same rate. They're growing at the rate gamma which is related to the net MP of capital and the MRTP, where one over sigma is a measure of how willing they are spread their consumption over time.

What does that work out to be in this model? The net MP of private capital determines how much people want to save and invest and is a function of the public/private capital ratio, the individual output elasticities of public capital and private capital and the private capital stock. Note that there is a nonlinear relationship embedded here.

Consider the two cases. In the neoclassical case with diminishing returns to private capital, where the alphas sum to less than one, there is a partial offset since there is an endogenous response of public capital. Nonetheless, there remain diminishing returns. Thus private capital stock comes to some level which is given by the ratio of public and private capital and the output elasticities. We're solving for some level of output in this case.

Compare this to the endogenous growth model where the sum of elasticities are equal to one. The two effects, working through private and public capital, are such that the MP of private K and MP of public K are such as to support the rate of return to private investment at some constant level so the incentive to invest remains at that level so that we can have long-term economic growth, not just short-term effects.

As Hulten pointed out, we would expect that private returns would be equal to public returns and that is consistent with what happens in this model. This model also can track growth changes over time. In this model we can measure the net benefit of public capital investment by taking the integral of the area between the growth rate at the optimal public investment level and the chosen public investment level.

A key thing about those benefits is that it depends on the rate of convergence, call it theta, to its long-run equilibrium. We want an estimate of that rate of convergence. The lower the output elasticities, the faster the convergence to the optimal level, and the greater the net benefits. This also gives us an estimating equation which is inherently nonlinear which relates the rate of economic growth in the transition period across steady states to public to private capital ratio, the original level of output in the economy, the output elasticities and the rate of convergence.

The picture is similar in the endogenous growth model except productivity growth rather than output levels is the key variable. Again, the MP of private K will be equal to the MP of public K in the optimum. The net benefits are similarly calculated by an integral which here does not depend on the rate of convergence since this is an endogenous growth setting. Our estimating equation relates productivity growth with public/private capital ratio, the output elasticities (we only need one since they sum to one) and some parameters of underlying preferences of the consumers.

I've actually run some regressions using Munnell's data. Munnell has data on public and private capital stocks from 1970 to 1986, by State, for the 48 contiguous States. I've cut her sample in half for 2 periods of 8 years each for 96 observations. This first set of results is an estimate of the endogenous growth model using nonlinear least-squares. I'm estimating the intertemporal elasticity of substitution in consumption, one over sigma. This estimate isn't too bad: most estimates are up to unity, so this is a reasonable estimate presented here.

I don't care about that number too much, though. The estimate of the output elasticity of public capital is in the range of 0.28 to 0.31. That is somewhat higher than Munnell's paper because she was looking at the relationship between output, public and private capital and employment in the long run in levels. However, this estimate is not as high as the aggregate elasticity estimates which came out of my work and Munnell's early work. Notice that the point estimates of the important variables stay about the same if one includes regional dummy variables and a dummy variable for the 1970's.

One can pull out of this an implied public/private capital ratio which is in the range of 0.57 or 0.58 to, say, 0.63. In these data, the actual level of public/private capital is in the range of 0.43, which implies that there is substantial underinvestment on average in some of these States - some would be overinvested, some would be underinvested. Calculating the integral one would arrive at the net present value of the benefits of increasing public capital investment to its optimal level. Raising the public/private capital from 0.43 to 0.53, a 10 percentage point increase, would yield a present discounted value of net benefits somewhere around $1 trillion, which is very large. The underlying investment to do that would be somewhere in the range of $500 billion, yielding a B\C ratio of somewhere around 2.

This is very restrictive because we know from Barro that there is a tendency of States' growth rates to converge. If we add in the initial level of output, in a neoclassical setting, the lower the initial level of output, the faster the economy will grow because it is catching up to other economies in terms of level of output. Adding this in, one obtains a estimate of beta, the convergence rate, of 3.1 percent per year. This is similar to other estimates. This reduces the estimate of the output elasticity of public capital by about 5 percentage points from 0.3 or so to 0.24. What that implies is that the optimal public/private capital ratio is pushed down from around 0.55 to around 0.48, only 5 percentage points higher than the actual average of 0.43. The present discounted value of net benefits of increased public capital investment is thus somewhat less.

Finally, one can add a specific transition equation for output growth as one moves from one steady state to another. This brings us to the neoclassical growth model. This causes a substantial reduction in the output elasticity of public capital: before it was close to 0.3, then down to 0.25, and now it is down to 0.18 to 0.2. This result is right on line with what Munnell obtained. We can also estimate the output elasticity of private capital since we are no longer constraining the two capital elasticities to sum to one. The output elasticity of private capital is free to find its own level, which in this case is estimated to be around 0.5. At first blush, this seems very high: in a strict neoclassical growth model, one would expect such an elasticity to equal 0.3 or less, less if there is positive output elasticity of public capital. However, this estimate is remarkably similar to estimates obtained from cross-country estimates with the sum of the elasticities being equal to 0.7, lower than the endogenous growth model, but suggesting very slow diminishing returns to public capital.

Hulten: Can we read that as saying that the labor share is the residual?

Aschauer: That's right; there is the underlying constraint that alpha K plus alpha G plus alpha L is equal to one. This is almost the same as the cross-country comparison I mentioned before except here public capital is substituting for human capital.

In this neoclassical model, the optimal public/private capital ratio is pushed down considerably, from 0.51 for a high to a low of 0.417. In this latter case, it is below that actual ratio for the period, which is to say that infrastructure was overinvested across the States. If you calculate the net benefits in this setting of raising the public/private capital ratio by 10 percentage points, from 0.46 to 0.56, as we did in the endogenous growth model, a roughly $500 billion investment, we would generate, on net, a range from -$28 billion to $172 billion, which at the high end is B\C ratio of 1.2.

These are only exploratory numbers. There are a number of possible extensions to this work. Everything I wrote down implicitly assumes that the States are closed economies, so we have to take into account the possibility that either labor or capital might be attracted to a particular location if returns are high. However, Barro and others find that relatively little of the convergence is due to factor mobility.

We can also extend the model to include spillover effects, which I go into detail in the paper. In this case, one can allow total factor productivity in any particular State to depend not just on its own public capital stock, but also the regional capital stock. Thus we can explore some of the different results found in the literature at different geographic levels by examining different sets of capital stock data, State, regional or national. It would also be possible to have diminishing marginal productivity and diminishing marginal returns to public capital at the national or regional level, but not at the State level, so we can rationalize some of the divergences found. We can also pull out an estimate of how the economic growth rate depends not only on its own public/private capital ratio but also the regional public/private capital ratio and we can also pull out an estimate of beta, the long-term rate of convergence, and calculate the net benefits of increased public capital investment. We can also pull in omitted variables of one's choosing and see how they affect the results.

Lyon: It seems so intuitively obvious that one should endogenize public capital...

Aschauer: I'm doing it in the simplest possible manner, allowing public capital to automatically respond to changes in private capital.

Lyon: Why has it taken a number of years to do this?

Aschauer: We can think about doing it in an ad hoc fashion, adding on equations as needed. This model arose because of Barro's work where he endogenized the level of government spending on consumption and potentially on investment, though he didn't have any public capital. He did that because he wanted a model that would produce endogenous growth results explicitly. His intent was not to endogenize public spending for the purposes of understanding that better but to better understand the effects of government spending on long-term economic growth.

Eberts: When I did work of this type, we were interested in the determinants, at the local level, of the allocation process of public capital, which actually picks up on the simultaneity of causation issue where he we have public capital causing an increase in output or income and income being a function of the demand for public capital, so it was that issue we were exploring.

Aschauer: Yes, but it's ad hoc.

Eberts: Yes, it's not worked out in a regional growth model, but it has a foundation in the sense of the determination of public capital.

Aschauer: Yes. I'm not saying it's arbitrary.

Nadiri: Tatom didn't do that in some work with Hulten?

Aschauer: I think it's the case that much of the movement in public capital is in response to demographic and other changes, but we haven't had a formal model capturing this.

Hulten: My paper for the World Bank made the point that this sort of Arrow-Kurz model is the way to approach things and that if the economy does in fact unfold along one of these growth paths that there will be an extremely high correlation between public and private capital and output growth and you really need to go to this kind of framework to pick out the effects.

But that leads to a question. If this is the right framework, and I think it is, then treating public capital as an exogenous variable, as in a production function, would lead to a very high estimate of the output elasticity of public capital, due to the factors that you're now controlling for.

Aschauer: We don't find that using State level data in a production function approach. But there is an observational problem in terms of the data because we would expect a relationship between output elasticity and steady state output. However, we don't observe steady-state output, so for you to make that argument you would have to assume that we are already in the steady-state output.

Hulten: But it is also a characteristic of the optimal transition too. At least it's true if you're making the transition to the optimal level where MP's are equalized.

Aschauer: If you're in the optimum, but I'm not assuming that with these estimates. What I'm saying is that if we were at the optimal level, there would be an equilibrium between the MP's, but I'm not imposing that on the model. A number of States might be above the optimal level, a few might be at it, and some would be below.

Gordon: In the end of your process, you're getting some optimal ratio of public to private capital...

Aschauer: Yes, from an elasticity estimate we can pull off that estimate on average, across States. We have information that shows that State A has overaccumulated and State B has underaccumulated, but only if we're willing to assume that technological parameters are the same across States.

Gordon: I guess my question comes down to what's the policy usefulness of this exercise, given that you have to assume a lot of the answers to questions that policymakers are in fact trying to answer and given that you're still talking about fairly aggregate types of statements under fairly restrictive assumptions. I see the value-added from a theoretical perspective, but how does much does this really add to policymaking abilities, at least within the time-frame of this project?

Aschauer: Hulten was talking about micro-macro linkages, and I would be talking about the macro-micro framework. To the extent that this project would put aside some of the statistical concerns such as endogeneity, non-stationarity and spurious correlation (corrected for by relating growth rates to ratios of public and private capital), that would have value. In addition, we would have a different methodology, in a different framework, where we would be getting a different set of output elasticities which could be compared to those already existing.

The model would also give more information about the extent of regional spillovers and give us more information about the relationship of public capital to economic growth and allow us to estimate the type of net benefits we would expect to get.

I think that the work is valuable on its own grounds. Let's look at the alternative, which might be to estimate production functions at the industry level and estimate elasticities and compare them with what we're getting with, say, the cost-function. But I would argue, and I may be arguing myself out of a part-time job, that the statistical properties of the cost-function approach are superior to those of the production-function approach, even though duality should tell us the output elasticities should be the same. However, we still want to know what the aggregate impacts on the economy are of public investment.

Jacoby: How applicable is this analysis to even lower levels, such as the firm? Could the G variable be estimated for public capital used by the firm versus its own capital stock?

Aschauer: You could take this analysis down to the sectoral level, but not to the firm level. For example, Barro finds that without public capital, the convergence effect is much stronger in manufacturing than in wholesale and retail trade. You could certainly make statements at that level.

Jacoby: So you could then make statements about the relative importance of infrastructure improvement in the manufacturing versus the service sector and so on?

Aschauer: We could pull out of this some estimate of the output elasticity of public capital in manufacturing relative to wholesale and retail trade and from that we could estimate some of the effects on convergence and see what the long-term impacts are on economic growth in those industries.

Jacoby: And did I understand correctly that the lower my initial capitalization, the longer the convergence the period and therefore the larger the integral?

Aschauer: What I was saying was that the greater the diminishing returns to capital, the quicker will be the convergence effect.

Jacoby: O.K., and that's the higher the level of capitalization in general.

Aschauer: Yes.

Eberts: You mentioned Barro's finding on factor mobility and I wonder if Hulten could contrast that finding with his work.

Hulten: Bob Schwab and I have updated that work with respect to technological convergence. Where we have intermediate goods in there, we partialing out the direct effects of infrastructure - purchases of transportation, purchases of electricity, etc. are already factored out of the analysis. When you take that out, we don't find convergence or a big externality effect. What we're finding is that largely the intersectoral flows, the migration of labor and capital, seem to be accounting for the differentials in productivity growth across regions. How this holds up at the industry level, we don't know yet, whether this is just an aggregation phenomenon or something real.

Eberts: Barro's finding that factor mobility accounted for only 10% of productivity growth seemed to go against what you found in 1984 which showed that factor mobility played a large role.

Hulten: We continue to find that result in manufacturing. But this is a very different data set.

Aschauer: Barro's was for the aggregate economy, using personal income and gross state product. But in the model, Barro was focusing only on labor mobility, and it is this to which that 10% figure is tied. When he did break it down, he found faster convergence in manufacturing, though he did not analyze the sources of that convergence at the sectoral level.

Hulten: What Bob Schwab and I are finding enables you to go forward with this, for if we did find vast differences in sectoral technologies across areas, you really would have difficulties in generalizing to the economy at large. At least in manufacturing, we find that everyone is drawing from the same pool of knowledge, and that the question is whether you have the activity in the region to start with. Given that you do, you draw from the prevailing stock of knowledge.

Albright: One of the goals of this effort is to look at the different functional infrastructure categories. How applicable is this analysis to this effort?

Hulten: Conceptually, there is no difficulty with such an effort. Empirically, one has to have sufficient data with sufficient variation across States.

Albright: Do you have any ideas of whether the impacts will be different from what's currently found in the literature?

Aschauer: As a matter of fact, I have applied this work in the endogenous growth framework to look at core versus other infrastructure and have found that core infrastructure is more productive. I don't how far we can go from that point, but one would hope to get different elasticities for different types of public capital.

Eberts: When you're disaggregating these different types of public capital stock and public capital versus private capital, are you looking at each type separately?

Aschauer: What I always do is to always include the complements in the regression. So, for example, when I look at highways, I am also looking at all other types of public capital.

Eberts: And that would then be for one industry, and then you would do the same thing for another industry?

Aschauer: In other words, could one look for spillovers across industries? I would think that would be more of a strict summation than spillover phenomenon.

Hulten: You would use a Divisia index to aggregate across the regions?

Aschauer: I thought that we were just talking about hunting for spillover effects.

Hulten: It seems to me that when you do that, one possible solution is to weight by the output shares to avoid picking up any aggregation bias.

Infrastructure Capital and Productivity Analysis: Cost- and Profit-Function Approaches

Nadiri's Presentation: We have encountered today some of the difficulties of coming out with some of the practical answers to the issues which infrastructure raises. Hulten was talking about an almost impossible world which is a challenging world to those applying the theory and, at least to my knowledge, we are nowhere near coming to grips with it, although Hulten's theoretical points are well-taken.

A second issue is that public capital is treated as some kind of a residual which must be compared to private capital and which is often judged to be deficient on that basis. However, there are reasons to have public capital which are not comparable to the private sector rationales.

David Aschauer mentioned this model of optimal growth which would show the relationship of public capital investment to long-run economic development and growth. I have a much more applied model which might fit in well with Aschauer's model. The elasticities Aschauer is estimating are critical to determining whether existing levels of investment are optimal.

First, I try to modify the relationship between public capital to private capital with respect to total factor productivity. My view is that the relationship to aggregate demand, or State demand and productivity growth has never been explicitly explored. Now it comes from either a production function or a cost function where we assume that output is given and then off we go calculating the productivity effects. The question is can we incorporate the demand side into this analysis.

Second, in order to get rates-of-return for public and private capital, you need to get more theoretical and econometric structure into the model. The cost analysis provides a more reasonable approach than the production function. Because you utilize the side conditions regarding shares of labor and capital and so forth, you get more structure than what you would get from the simple description of technology inherent in the production function. I would suggest that this lack of structure may be part of the cause of the high elasticity estimates found thus far.

The following types of questions would be attempted to be answered. First, what are the rates of return to public and private capital at different levels of aggregation, in particular at the industry level? Then what are the employment effects across industries? Also one could calculate the complementarity and substitutability among the private capital and public capital across States and by industry.

Some years ago, I published a study of the spillover effects of R&D in the interindustry and intraindustry effects. This framework could be used to examine, in principle - I have not done the estimates - the intrastate and interstate spillovers. In addition, we can introduce different types of public capital into the analysis, though this is not easy.

One may also estimate the social rate of return to different types of capital to show whether there is over- or under-investment. Whether these estimates would be correct is another question. Network effects cannot be estimated under this framework, but there is some analogous work done for telecommunications, for example. However, most of the work on network effects remains theoretical. Perhaps if the network is specified as a function of the size of the network and perhaps the density, then perhaps one could develop some measure of the capital utilization or capital services of the public sector.

I don't know if we can do it, but my framework assumes that network effects are proportional to the size of public capital.

The next issue is how do we approximate the level of capital services and the effects of congestion on those services. This can be accommodated, though it is not an easy issue, since public capital is in the cost function.

I am assuming that there are two economies-of-scale parameters in the cost function. One parameter refers to the returns to private capital in its own private production function, and the other parameter includes both public and private capital. If public capital is at all productive, then it should either be lowering costs or increasing output, and since the firms are not paying for the capital directly, then the public plus private returns should be greater than the private returns, and you can estimate this difference. This model does not assume constant returns to scale, which can be estimated.

This model contains a demand equation takes into account the effect of population, aggregate output and own-output so you can get an inverse elasticity of price. The supply side is represented by a translog function which is much more flexible than what is called the McFadden function.

From this system, productivity growth is attributable to four items: population growth, relative input prices, technological change, and public sector capital. Public capital will have two effects of productivity. One is a direct effect which shifts the cost function down. When this shift occurs, the existing deployment of private resources is not optimal and so there will be an indirect effect as well.

My estimates have shown that the indirect effects vary greatly across industries. Some industries are more sensitive to population changes, others to relative input prices, and others to technological change. Thus one would get a distribution of elasticities which one could average to get a broad measure which could be then input into Aschauer's model.

Then there is the question of how these output elasticities change by level of aggregation. It may be useful to have these industry-level estimates and examine aggregating them up. It may not be possible to do this, but it can be explored in this model. It is also possible to examine regional differences.

It is also possible to examine spillovers from one State to another, but this gets hairy. For example, it is possible to see that roads in one State have effects on roads in another since they are connected to one another, but it is hard to see how the sewage system in one city is linked to another. One must be aware of instances where the connectivity does not exist and take this into account in the analysis.

We need a consistent set of underlying estimates of the parameters at different degrees of aggregation and test some of these hypotheses which have been floating around. This analysis does not deal with the project level, but it could provide a distribution of parameter estimates which could be challenged and understood a bit better.

Hulten: You're very well-known in the research community for having pioneered adjustment cost models. It seems that some of the public capital-private capital differences might be approximated using adjustment cost models, for example in network effects.

Nadiri: Yes, that would put the analysis on a more dynamic footing and could handle some of the problems associated with building in advance of need.

Holleyman: You're doing this analysis at the industry level. How are you aggregating these results up, particularly given nonconstant returns to scale?

Nadiri: My first cut would be to get the estimates. We really don't know how to aggregate except under very strict assumptions. One alternative is to fit the same function to different levels of aggregation and see the results. This is not very satisfactory but it will provide some distribution of estimates.

Eberts: Could you talk about some of the data requirements?

Nadiri: Many people claim that cost-functions require a lot more data than other approaches. This really is not true. Most of the output data are in nominal terms. You need a price deflator and you need a measure of investment to get capital stocks. You need wages, and a Jorgenson-type of user cost of capital. For the latter we assume a competitive capital market so that interest rates are identical across industries. You can adjust this for differing debt/equity ratios. The cost function requires a lot more work, to be sure, but the data are available.

Eberts: At the regional level, do you incorporate the local tax structure and other factors?

Nadiri: David Aschauer and I are looking at this possibility, but this is not easy. This is a first-order approximation right now, but hopefully we will develop a richer data set which can be used for many other purposes.

Eberts: One problem is that estimates of private capital stock at the local level are so poor.

Nadiri: I do not know of any study of capital investment at any level that does not have problems. We have to try to avoid making new mistakes, but they will be there. We could avoid using capital stock at the industry level entirely if we have an aggregate capital stock measure and assume that the individual industry is in the long-run and has no internal cost of adjustment, but this approach presents its own problems. We will cross that river if we can get to it.

Rubin: If there's a bridge there. (laughter) Your paper implies that you could use your results to answer a bunch of policy-type questions. Is that right, and how much confidence do you have in those answers?

Nadiri: There is a debate about why the public capital is in the cost function at all and how should it enter. This difficulty I assume away, but I can offer a theoretical justification. Imagine a world where there is no public capital - would private production be viable? It seems reasonable to say that the public sector has a role in the production of the private sector. I do not have the answer to that, but I want to look at the data and see what it says.

Beyond that, one could answer how much public capital changes costs in a particular industry in a particular place. There are many variations to the analysis which could be undertaken - regional, State, sector and so on. Some issues such as networks and club goods exist but do not have ready solutions.

Albright: The permutations of the work could be extensive. What do you think are the most fruitful first steps?

Nadiri: First, do not include too many categories of infrastructure types. If you have 6 or 7 or 8 types of capital, you will have intercorrelations between them and will have a very difficult estimating job. One alternative is to develop some index of these various types which we can get from some sort of weighting function based on theoretical and other grounds. If you can develop this weight you can assess the relative impacts of different types of capital.

One may also develop prototypes. For example, you can analyze one industry for all States, or States only without industry. That decision would depend on what questions you think are most relevant.

There is an interesting issue that when you build a road, that moves the population there and increase the demand for output. You could empirically measure this impact by looking at the effect on demand, with the appropriate lags. But there must be a strict limitation on what you do.

Hulten: I think that last point is a very important one since the endogeneity problem can crop up in this dual approach to the production function. The high-cost regions are the ones with the lowest output which means that the demand for additional capital is lower and you have slower capital stock growth which is driven off of costs and not the other way around. One way you may get at this is through the lags.

Rubin: You mentioned earlier on that you would look at the quality of the capital services, i.e. congestion.

Nadiri: If you do not adjust for congestion and utilization, you get quite different empirical results. We have to adjust capital stock to account for utilization rate. How we do that is no easy matter. How for example do we account for congestion at specific times at specific locations? For example, this congestion does not occur at 4 in the morning.

Rubin: It just struck me that if we started just with one region, or if we knew of data which existed for one region, that would be an easier job than the nation as a whole.

Nadiri: That is true, but then you cannot generalize so easily. I would suggest that such exercises are better for calibrating aggregate estimates to see how sensitive they are to different situations.

Discussion of Next Steps

Lyon: We have seen really interesting work. It's useful, but it deviates from the original scope of work, which I think was arrived at through a consensus effort and still is a good idea. The other problem is timing - both the macro and micro people would have to do a lot of work.

Eberts: To me there are two questions and the two methods answer different questions. The macro function answers the underinvestment question and it has achieved its purpose of focusing attention. The micro approach tells you where to invest and that is where the focus should be. Trying to say that one is better than the other one is not the right question. We already have the nation's attention, or Congress'

attention, on the problem of infrastructure. Now what investment steps should we take next are better spoken to by the B\C approach.

Lyon: You're exactly right literally. I was merely suggesting B\C might be missing something and we want to identify it. B\C analysis is critical for looking forward and that is why we need to get that technique improved.

Gelston: Are you suggesting we derive some multiplicative factor to be applied to all B\C analyses to account for these deficiencies?

Lyon: No, I merely am suggesting that divergences would offer clues to where and why these differences occur. The baggage I'm carrying with me is that when we do these B\C analyses, we don't find loads of great projects and yet the historical evidence shows high returns. So the question is whether we have reached diminishing returns or are there some opportunities still out there yet to be exploited?

Eberts: I picture this in terms of the network. That's already in place, and the question is what impact the addition of some links to other nodes will have. The macro approach will capture the impact of the whole network, not of these additions.

Hulten: Having approached some honest B\C people, they finally found someone who would do this work [laughter]. I entered this project thinking we would never marry the two approaches. The real question is when is the plodding approach good and when is the big-think Schumpeterian approach appropriate. There is an analogy to the private sector. Some investments are carefully analyzed and can be so as when you're adding new capacity to a known market. Other issues are Schumpeterian leaps of gut instinct, such as mergers and moves into new countries. The same issue arises in the public sector, such as maglev. This is how the space station was sold and that is how the Louisiana Purchase was sold. Sometimes you're wrong, sometimes you're right. This may be where the macro approach has the most usefulness. You're not going to put these approaches on equal footing. You're going to have to develop tools for the appropriate situations at hand.

Jacoby: But the macroeconomic approaches, no matter how glitzy or sophisticated they may be, are no substitute for vision and leadership. Remember that Schumpeter said that the problem was not capital, it was the narrow-mindedness of bureaucrats.

Eberts: It appears that the data you've uncovered so far has already been found. We should move beyond data where you've basically redone a lot of existing work to new approaches in modelling.

Albright: We have expanded on the data of Bell and McGuire, though the underlying data is the same, but not all of it may be relevant to B\C analysis, and that presents some particular challenges which might be useful to address. I might also add that the intent of this project is not project-level analysis.

Jacoby: What we have seen is that a lot of effects like the complementarity between inputs are not captured by traditional B\C analysis which are important. After all we are investing in the economy, not highways. If you do not put these elements in, even informationally, then decisions may be made poorly.

Gordon: Following up on that point, the agenda as I see it is the original motivation of the project: to do a controlled comparison which might reveal patterns which would provide clues to how infrastructure affects the economy and identify promising avenues of further research.

Now that was the original scope of work. Some months have passed and we know more. We have collected additional data, but have not uncovered a mother lode. We have three proposals for new research which contain a lot of new thinking. Given the constraints of time and money, and given that we're not in the business of basic research but must come up with policy-relevant findings, we have to ask what should be in the final report and how should we get there. Maybe the original approach is still the best way to go, but maybe it's not. That is what I'm struggling with.

Gelston: Thinking of it from a broad policy standpoint, maybe the Aschauer and other macro-approaches can give you a tool which can tell you the relative effects of infrastructure versus education versus something else. This may tell you whether you should invest in infrastructure or education or something else.

Nadiri: Research I've done shows that R&D and infrastructure have similar payoffs - output elasticities of 1.2 and 1.5 respectively - education a lower payoff, around 0.5. Yes you can develop some differential rates of return. But I'd agree with Hulten that you can't marry the approaches - they answer different questions.

Jacoby: I would not advocate that the econometric approaches be incorporated in the project level analysis. I would want that analysis of larger effects at the programmatic level, then build up to the national level and sort out projects with B\C analysis.

Hulten: The danger is that the network effects or spillover effects may affect the ordering of projects. We should have criteria to show what situations where B\C analysis is dangerous.

Rubin: Hulten's approach is useful in that he gets around, in a certain sense, the aggregation problem, by noting issues which are important in measuring consumer surplus which is the basis of B\C analysis and which provides the first steps for aggregating up from projects to programs. Hulten is showing the things which are important if you want to fully capture the consumer surplus from individual investments.

Lyon: But the problem is that you have to get empirical. We will be required in the next couple of years to do good infrastructure analyses. It would be useful to have some high-caliber empirical work which would lead in that direction.

Rubin: But Hulten's work is going in the right direction, but you're right that it is by no means enough alone. It is true that we're not going to be able to do that within 2 to 3 years.

Lyon: I disagree. I think we can do programmatic analysis now. For example, the Clean Water Act could be analyzed for $200K and get 80% of the task. You could spend $2.5 million and get a better answer. In terms of data, we may have reached the limits in terms on input data, but maybe, if another year of data collection is going on then maybe the contractor should get together with the agencies and collect benefits data through contingent valuation or hedonic pricing or other methods.

Rubin: I guess I'm not an advocate of collecting more data, even on the benefits side. I think that if we believe that the effects of infrastructure investment are nonlinear then you're not going to capture them by collecting benefits data within the traditional linear B\C framework. I think Hulten has mapped out a path for describing that nonlinear world. I grant you that that is very different from our initial conception.

On the other hand, Aschauer's analysis can teach you a lot about the payoffs from network versus non-network capital. The network capital should have a much higher elasticity than non-network capital. His approach also shows some promise for estimating some of the benefits from environmental investments and other quality-of-life impacts.

Lyon: Not with existing data. Where are you going to get the value of travel time?

Rubin: I think that you can argue that the labor productivity term captures that impact, though I have to think about it a bit more.

Jacoby: On a somewhat more abstract level, what is going to drive the agenda for the next 4 or 5 years? Is it going to be project selection or is it going to be the impact on jobs, sectors of the economy, industrial policy? There is a certain focus that we need to develop as to what this product is going to be and how it is going to contribute to a larger agenda. The cost-function analysis for example, focuses you on the impacts on individual industries, which is another way of saying how competitive they are in the international economy.

Hulten: I agree with you entirely, Randy. The world would be a much better place if B\C analysis were done routinely. But in Congress, the decisions are made on a much more abstract level. One camp says that there should be a lot more investment, while others say that there is enough investment, and up to now neither camp has credibility. On the one hand, the macro approach exists in a sort of void unconnected back to any of the intuitions which people think they have now. Sure, the Intercontinental Railroad was a great thing, but what does that tell me about 1993?

By the same token, B\C analysis is allegedly drawn too narrowly. I was asked by a Congressman, when I was arguing for B\C analysis, "Don't you think you would have missed the Intercontinental Railroad?" Probably - who would have guessed that California would be so wonderful? (laughter) One of the reasons that I thought this project would be worthwhile was that we could build up our intuitions and understand when those high elasticities might be justified.

Lyon: That is exactly my desire. That is why I want to compare the two on the same data set and see how the results compare.

Hulten: What do you mean the same data set?

Jacoby: Maybe the same problem.

Lyon: I'd like to have the truth.

Hulten: There's a difference between finding out what the truth is, which we would all like to find, and seeing how sensitive different techniques are to what the underlying reality might be. For example,

through the National Science Foundation (NSF), Fermat's last theorem was not proved but simulated. Your data in most cases is somewhat synthetic.

Lyon: What I see is that we have the macroeconomic estimates which is one version of the truth focused on one broad question and we don't have the B\C analysis for the problem, while at the project level we don't have a macro-analysis, but we do have a B\C analysis. I'd like to see whether we would get the same results if we applied the two methods to the same problem.

Hulten: But you don't agree that you need to do something to see what the interesting issues are?

Lyon: You would learn something, but I guess that in that case you would find that a high payoff B\C analysis analyzed econometrically would have a high elasticity because you've constructed it that way.

Hulten: I will generate three underlying data-sets and I will give Nadiri and Aschauer each set and I will know the equivalent variation. I will sneak increasing returns in there and then let them do their thing. Then they will get their results and I will reveal the true answer - it's like a game show where the audience knows the answer but the contestants don't.

Lyon: I see what you're saying.

Starler: You know the pendulum on these meetings has swung up and back but hopefully each time we have some more information and I think we do. My pendulum right now is telling me that we should try to enrich B\C analysis to pick up things which the macro analysis might be capturing. I can't see right now the value of the original conception of using one method to validate the other.

Nadiri: Look at this way, when Hulten generates this secret data set, he cannot give us identical data-sets. You have to know what questions you need to answer to get the data you need. Even the nature of the data is different - one type deals with what the program does for the economy, another type deals with something else. They might be complementary.

Jacoby: It would be good if we could agree that there are wide areas of complementarity between the approaches, then agree on what those areas are, and then assess which area would be most fruitful to pursue given data availability and so on. I was always uncomfortable with the comparison of the two approaches because it set the wrong tone of a House divided.

Albright: One of the goals of this effort was not to have a competition for competition's sake but to set some boundaries on the reasonableness of the estimates. Since that time we've moved along the track of building a bridge between the macro- and micro- approaches and this will yield differential results to analyze. I think that this meeting indicates that it might be very difficult to do programmatic B\C analysis anyway and that it might not be directly comparable anyway to other methods.

Gordon: Before anyone leaves, I just want to get some sense, given the different approaches that they've heard, that there is a sentiment for reorienting the scope of work away from the comparative exercise to a more joint approach.

Gelston: People have been hammering away at government saying that more B\C analysis should be done. If I understand what you're saying, you seem to be indicating that we'll move from B\C analysis to some sort of blend. Who are you going to sell that to? What is the end result?

Gordon: How practical this is a question, but let's take Hulten's approach. For example, one would continue to do B\C analysis and then Hulten's analysis might be used to indicate where the possibilities of increasing return are greatest or least, where network effects are greatest or least and so forth. This wouldn't get you the whole way there of developing an understanding of how different investments would lead to different economies, but it is a first step, a linking step between the micro- and macro-approaches. It suggests a reorientation of the scope of work that I have to work on and I just want to test the notion of whether that's necessary.

Jacoby: You've captured my sense of things pretty well. At our first meeting, we had Bob Stearn's eight questions, and I remember saying to myself that B\C analysis answers the first three, while the others were either had no answer or had only econometric answers. All available knowledge should be brought to bear on the problem, with the possible exception of what Aschauer laid out, and I say that only because I don't yet understand fully what he was laying out. But that's my problem not yours.

Starler: I'd like to ask the panel for their final words of advice.

Aschauer: I really believe that much of what is going to be going on over the next five years are going to focus on a different set of questions than that focused on by B\C analysis. All the work that Nadiri is going to do requires, for example, that prices be set in advance. B\C analysis is important for allocating funds, but we also need to know what level that budget should be set at and the distribution of that budget. Basically I favor doing some sort of macro-analysis.

Hulten: Basically, we need to know how the economy works. We're not going to know with this project or the next 20 years of economic research. The last 20 years of research has sought to bring together microeconomic theory and macroeconomic theory, in a largely unsuccessful effort. At this stage, I don't think that's there's more than we can do than probe.

A second point is that infrastructure is dominated by the budget. Robert Reich thinks we should spend $200 billion more a year. If by some miracle we are able to do that we are going to be spending money right and left without any constraint. We need to know the boundaries and be able to answer and assess the calls from the ramparts for more spending.

Nadiri: This analytical marriage of B\C analysis and macroeconomic analysis is not around the corner. They answer different questions. To me, as limited as these production and cost function methods are, we need to understand where the effects are and add additional information wherever we can get it. The economic questions which are interesting to me are the effects on employment, regional income and so on. B\C just does not answer these questions. Econometrics uses averages in its estimates - an average price or what have you - while policy questions deal in increments. They are different approaches and it is going to be very difficult even to bring the approaches into conformity with one another. They are just different. I mean, one is going by railroad, the other going by truck.

Lyon: In the private sector you'd have your financial statements and analyze them and choose those projects which have 10 to 15 percent return. Now you wouldn't throw out those projects if your

econometrics indicated a different rate of return. Why would we do this in the case of public investments?

Nadiri: But in the private sector, people have calculated the average rate of return on an investment of a particular firm. On the other hand, if you are making an increment to a system, such as a cellular phone investment, then you might employ B\C analysis which might show something different.

Lyon: I understand what you're saying: the econometric analysis is measuring average return while the B\C analysis is measuring marginal return, and the two might very well be different. But you wouldn't come along and say that my 8% return in my cost function shows that my 25% rate of return in my prospectus is wrong. Yet we might do that in public sector analysis in saying that my 5% return is wrong because we're missing network effects. Maybe we're not missing network effects.

Aschauer: The private sector manager is asking more complicated questions. Does that manager care about macroeconomic impacts? No. You're putting forward a set of questions which is inherently allocational within the individual firm. If you're in the Federal government, you not only have to worry about allocating dollars, but setting the overall level of dollars as well.

Gordon: The objective function of a private sector firm is simpler than that of a government. That's one issue. Another issue is that private sector analysis may miss some of these effects. Take Sam Walton for example. When he was setting up a store in Arkansas in the middle of nowhere, traditional B\C analysis may have led him to believe that this was not a good investment. Walton, on the other hand, took aerial photographs and thought about market potential and then made his investments which paid off. In some sense one could argue that he was doing a full-bodied B\C analysis. That gets us to the original intent of this project, namely to enrich B\C analysis and to enrich macro-analysis to get a better understanding of infrastructure in the economy. Originally we proposed a comparison of methods to get at this, but at least what I hear the panel saying is that this comparison might itself be more trouble than its worth. I'm not necessarily rejecting the idea of a comparison yet but I am struggling with the notion of the best way to go.

Robinson: I think the analogy with Sam Walton is applicable in that he didn't have to worry about draining the business from downtown. The Federal government has to worry about it.

Gordon: Are there any sort of final thoughts to be put on the table before we leave?

Stakhiv: Let me give you a few thoughts. When this project was originally conceived, we thought about how to assess the Aschauer model by doing some comparative analysis of different macroeconomic models. The other issue was that when you deal with the performance of infrastructure and have already decided where to invest, are you really getting what you expected to get and are you choosing the right scale of the project. Finally, we wanted to update the national performance report of the National Council on Public Works Improvement using new data. That was the original intent. Cameron poses the right question when he asks whether we should stick with the original scope of work or move beyond it.

Rubin: Cameron, can you give us a sense of what you're going to do next?

Gordon: I assume what I will do is write up several options of where we could go, one of which is to simply press on. Then I will call people and get a read of things and move forward with a formal work plan which will then be executed.

ENDNOTES

1. IWR/ACIR, 1993.

2. These eight questions, asked with reference to the scope of work being discussed during the previous three workshops, were:

1. Are we able to define the optimal levels of infrastructure investment?

2. Has the work helped us to determine the priorities of investment within a single agency?

3. Has it helped us to determine how to select among projects in agencies along with the associated tradeoffs?

4. Has it helped us decide whether operations and maintenance, major rehabilitation, or replacement is the best strategy for a given infrastructure, given the facility condition and budget?

5. Has it helped us to develop a common language among Federal agencies on this issue?

6. Does it tell us what data we should be collecting to make informed decisions in the government?

7. What does it say about the appropriate roles of the Federal government, state and local governments, and the private sector in an overall infrastructure investment strategy?

8. If increased public works investments are indicated, how are we going to pay for these investments and who is going to pay? For example, is the beneficiary pays mechanism to be used?

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This is the seventh in a series of interim reports which will be published by the U.S. Army Corps of Engineers during the Federal Infrastructure Strategy program, a three-year effort to explore the development of an integrated or multi-agency Federal infrastructure policy. This report introduces and provides an overview of Phase II of a study to assess the impacts of infrastructure on economic growth and productivity.

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